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ABSTRACT

This manual is intended to assist pesticide applicators to meet the requirements of the Michigan Department of Agriculture for certification. The primary focus of this publication is on forest pest control. An introduction with the explanation of pesticide applications in forestry is presented. The ten sections included describe: (1) Principal forest types in Michigan; (2) Forest insects; (3) Forest diseases; (4) Vertebrate populations and problems; (5) Forest vegetation control; (6) Pesticide labeling for forestry; (7) Special forestry application equipment; (8) Special precautions for pesticide use in forests; (9) Action of pesticides in the forest environment; and (10) Hazards of pesticide use and nonuse. A list of self-help questions and instructions for completing the questions are presented at the end of each section. (HM)

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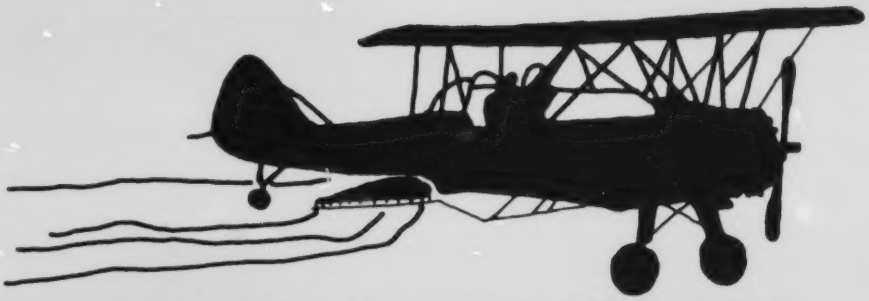
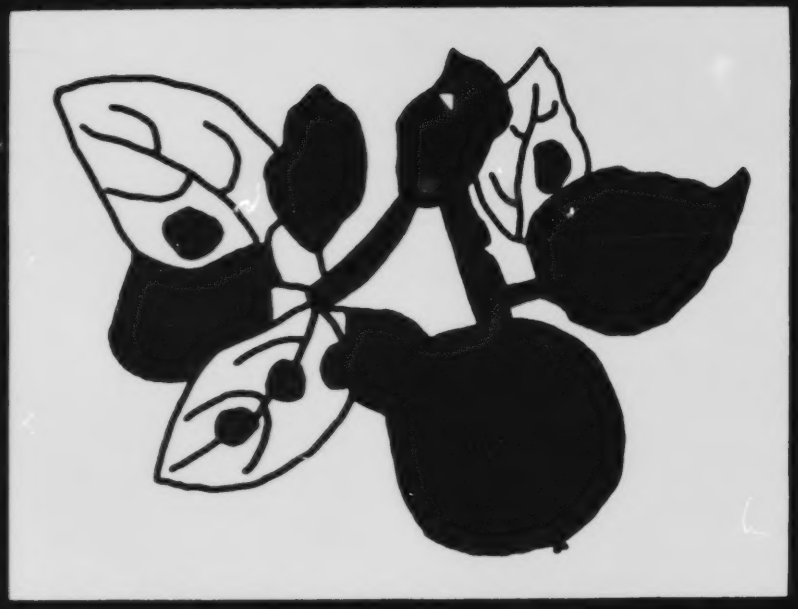
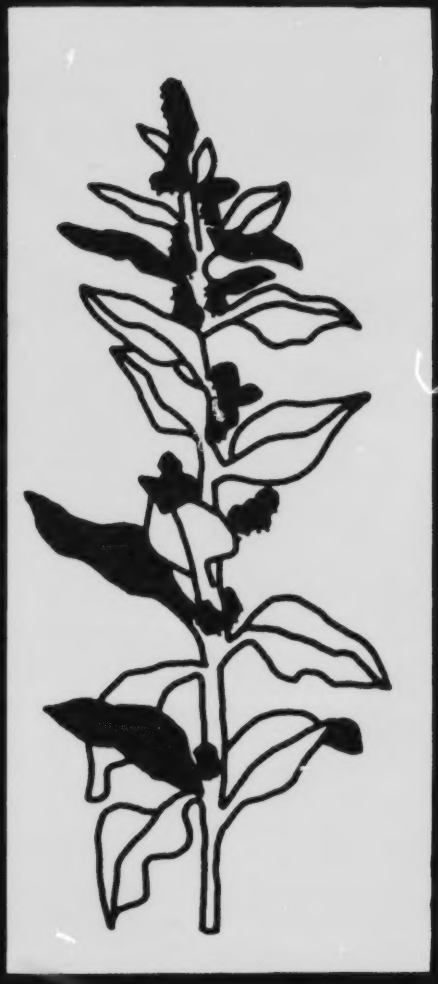


SAFE, EFFECTIVE USE OF PESTICIDES
A MANUAL FOR COMMERCIAL APPLICATORS





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PREFACE

This manual was prepared to aid foresters study for certification as pesticide applicators. The manual was developed by Drs. R. B. Heiligmann, Mr. Koelling, and M. J. Wallerscheidt of the Department of Forestry; Dr. F. Laemmlen, Department of Botany and Plant Pathology; and Dr. K. Kennedy, Department of Entomology of Michigan State University. A portion of this manual was extracted from a draft copy of a federal forest pesticide manual.

A list of self-help questions and instructions for completing the questions are at the end of each section. If you encounter difficulties in using the manual, please consult your county agricultural extension agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions on studying the manual are:

1. Find a place and time for study where you will not be disturbed.
2. Read the entire manual through once to understand the scope and form of presentation of the material.
3. Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.
4. Answer, in writing, the self-help questions at the end of each section. Instructions on how to use the self-help questions in your study are included with the questions. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.
5. Reread the entire manual once again when you have finished studying all of its nine sections. Review with care any sections that you feel you do not fully understand.

This manual is intended to help you use pesticides effectively and safely when they are needed. We hope that you will review it occasionally to keep the material fresh in your mind.

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INTRODUCTION

Forestry is a broad discipline, being defined as "the art, science, and practice of managing and using for human benefit those resources which occur on and in association with trees and/or forest land." This definition infers many products of the forest including wood, water, wildlife, forage, recreation, aesthetics. The management of the forest to obtain these resources or values includes determining for which resources or values to manage and the activities which will provide them including inventory; timber cutting for harvesting and/or the manipulation of stand density, species composition and/or quality; forest establishment (e.g., site preparation, tree planting, seeding, etc.); forest protection. Properly used, pesticides can be extremely useful in achieving many forest management goals including the control of injurious insects or diseases, the control of undesirable weed competition around newly established seedlings, the elimination of undesirable woody vegetation, and the control, including repellency, of vertebrate pests.

The importance of pests and pest management is not the same, however, for all forestry applications. To illustrate, control of a nuisance-type pest such as spring cankerworm is obviously more critical in a heavily used forest campground than in an industrially owned tract where wood production is the principal product. Similarly, control of nonfatal needle blight or twig cankers is more critical in a Christmas tree plantation where quality foliage is essential than in a pine plantation where natural pruning, particularly of the lower branches, is desirable. On the other hand, severe destructive pest outbreaks can destroy many years of forest growth and the application of pesticides to land managed primarily for timber production may be necessary under certain conditions. Thus, there are few firm rules regarding the use of pesticide materials in the practice of forestry. Rather, each situation must be considered independent of other operations, and decisions regarding the use of chemical materials made in accordance with local needs.

We have inferred in the above discussion some concern regarding the economics of pesticide application in forestry. To restate this point, there are some situations where the use of pesticides might appear desirable, but is uneconomical considering the cost and relatively low unit value of the final product. This is especially true in forest situations where low value products such as pulpwood or pallet stock are being produced. Forest stands of this type can afford few if any intensive pesticide applications. However, a forest of the same composition being used for recreational purposes might support such a treatment due to the higher value product being produced. In a similar situation pesticide applications to individual ornamental trees, or to windbreaks, Christmas tree plantations, shelterbelts, in parks, greenbelts, etc., frequently must be made, irrespective of the value of these trees for wood production.

PRINCIPAL FOREST TYPES IN MICHIGAN

The soils, climate and topography of Michigan are quite variable, and this variation is reflected in the several different types of forest present in the state. Nine differing forest types or associations have been recognized. Within each association the same principal species will be found, although the amount (percentage) of a given species within the association may vary from one location to another.

To facilitate discussion of pest problems and pesticide applications, we will consider the major forest types present in the state. Within each type certain pest situations can be expected.

Northern Hardwoods

This forest association is predominantly sugar maple with varying quantities of beech, elm and basswood. In southern Michigan, red oak, white ash and scattered yellow poplar and walnut are found. Farther north and in western Michigan, hemlock and yellow birch appear.

There are nearly 1.6 million acres of northern hardwoods in the Lower Peninsula of Michigan, most of which are second-growth stands. Two-thirds of this acreage is in the northern half of the Lower Peninsula.

The northern hardwoods constitute an important commercial forest group. Sawlogs are the most important product produced. Sugar maple is not only valuable for sawlogs and veneer, but also for maple syrup. Michigan ranks third among the states in number of sugar maple trees tapped, and fourth in production of maple syrup. The other tree species associated with the northern hardwood group are also important commercially for lumber purposes and pulpwood.

The most acute problems for this type of forest in farmland and adjacent woodlands are caused by grazing. When combined with indiscriminate cutting, grazing eventually results in a preponderance of undesirable tree species, understocking, and soil deterioration. In some areas of the northern part of the Lower Peninsula, deer browsing is a serious problem preventing or retarding the development of desirable species into sapling and pole sizes.

Brief descriptions of the principal species in this type are as follows:

Sugar maple

Beach

Sugar maple is a large tree often reaching a height of 60 to 100 feet with a trunk diameter of 2 to 4 feet. In forests it develops a clean trunk to a good height while open grown trees form a dense, round-topped crown. The leaves are opposite, simple, 3 to 5 inches long and broad, usually five lobed, the lobes sparingly wavy toothed. They are thin and firm, opaque, dark green above, paler beneath, in autumn turning to brilliant shades of yellow, orange and red.

The flowers are greenish and inconspicuous. The fruit differs from our other maples in that it matures in the fall and germinates the next spring. It is a two-winged samara or "key." The bark on young trees is light gray to brown, and rather smooth, later breaking into long irregular plates or flakes, which often loosen vertically along the side.

Beech usually attains a height of 50 to 75 feet with a trunk diameter of 2 to 4 feet. In the forest it is tall and slender, with a narrow crown; in the open it has a short, thick trunk and broad, compact, rounded crown.

The simple oval leaves are 3 to 4 inches long, pointed at the apex and coarsely toothed, becoming leathery when mature.

The bark is most distinctive, as it maintains a smooth, steel-gray surface throughout its life. Trees near frequented places usually have the bark carved with initials. The fruit is a stalked, prickly, four-valved bur, containing usually two triangular, shiny brown nuts with a sweet edible kernel.

American elm

American basswood

Northern red oak

White ash

American elm may reach an average height of 80 feet with a diameter of 2 to 4 feet, but often exceeds 100 feet in height with a diameter of 6 to 8 feet or more. Forest grown trees often divide into several large branches at 30 to 50 feet from the ground, while open grown specimens usually branch sooner and have a wide spreading crown of pendulous branches. Dutch elm disease has largely eliminated this species as a major component of the forest in lower Michigan.

The leaves are alternate, simple, 4 to 6 inches long, dark green above, paler below, doubly toothed, rounded at the base on one side and wedge-shaped on the other.

The flowers are small, perfect, greenish, on slender stalks, appearing before the leaves in early spring.

The fruit is light green, oval-shaped, with the seed portion in the center entirely surrounded by a wing. A deep notch in the end of wing is distinctive of the species. The seed ripens in the spring and is disseminated by the wind.

Basswood commonly attains a height of 60 to 70 feet, but often exceeds 100 feet, with a tall straight trunk 2 to 4 feet in diameter. Numerous slender branches form a dense rounded crown.

The leaves are alternate, simple and obliquely heart-shaped, coarsely toothed, dull dark green above, paler beneath. The flowers appear in June or July, and are yellowish white and fragrant, their stems attached for half their length to long narrow leaflike bracts. The fruit is nutlike, woody, about the size of a pea, and covered with short thick brownish wool.

The bark on young stems is dark gray and smooth, on old trunks thick and deeply furrowed into small scaly ridges.

Northern red oak attains a height of 70 to 90 feet with a trunk diameter of 2 to 4 feet. In dense forest, the trunk is straight, clean and continuous, bearing a small narrow crown.

The leaves are 5 to 9 inches long, 4 to 6 inches wide, broader towards the tip and divided into seven to nine lobes, each being somewhat coarsely toothed and bristle-tipped, and firm, dull green above, and paler below.

The acorn matures at the end of the second season, and consists of an ovoid nut covered at the base by a shallow cup which is velvety inside. The bark is smooth, gray to brown, becoming broken by shallow fissures into continuous, distinctly flat-topped ridges.

White ash is a large tree, usually 70 to 80 feet tall, with a diameter of 2 to 3 feet, though much larger trees are found in virgin forests.

The leaves of the white ash are from 8 to 12 inches long, and have from five to nine plainly stalked sharp-pointed leaflets, dark green and smooth above, pale green beneath.

The male and female flowers occur on different trees, the male in dense reddish purple clusters, the female in more open bunches.

The seed-bearing portion of the fruit is round in cross section and much shorter than the wing which does not extend along its sides.

The bark is grayish brown, rather thick on old trunks, deeply divided into firm narrow ridges.

Eastern hemlock

Yellow birch

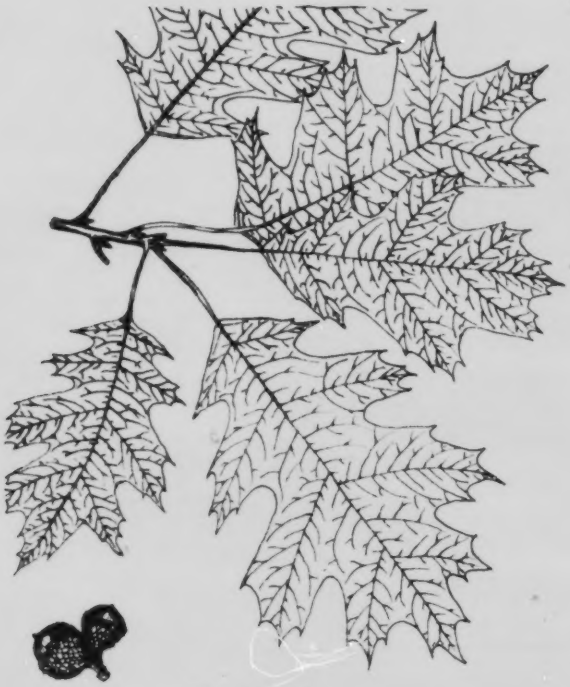
Eastern hemlock attains a height of 60 to 100 feet and a diameter of 2 to 4 feet. The needles are flat, oblong, rounded at the apex, dark yellow-green above and whitish beneath, 1/2 inch long, attached by minute stems or stalks, and fall the third season. They are spirally arranged, but appear two-ranked. The cones are only 3/4 inch long.

The bark is 1/2 to 1 inch thick, deeply divided into narrow rounded ridges, covered with thick scales varying from cinnamon-red to gray tinged with purple and was formerly peeled for tanning bark.

Yellow birch is usually 60 to 80 feet high with a diameter of 2 to 3 feet, but occasionally 100 feet high with diameter of over 4 feet. On the better soil the trunk is often clear for half its length, with a broad round-topped crown.

The leaves are 3 to 4 inches in length, ovate, acute at the apex with the margin double-toothed.

The fruit is erect, ovate, 1 to 1-1/2 inches long and 1/2 inch thick. The bark is close and furrowed, or peels off in thin yellow filmlike layers—on old trunks becoming thick, dull and broken into large thick irregular plates.



Black oak

White oak

The oak types are divided into two regional areas, one in the southern half and the other in the northern half of the Lower Peninsula.

In the southern half of the Lower Peninsula, the predominant overstory species are black, white and red oaks, with some hickory, red maple, black cherry and white ash commonly forming portions of the stand. Flowering dogwood and sassafras are common understory species. The stands are generally even-aged,

and occupy approximately 35 percent of the forested portion of the area. A large portion is in small farm woodlots 10 to 30 acres in size. Some of the larger areas are state-owned recreation or game units.

In the northern half of the Lower Peninsula, the predominating species are northern pin oak, northern red oak, white oak, and other oaks, with the stand composition often referred to collectively as "scrub oak." These stands are extensive in area, and occupy some of the former red and white pine sites which were repeatedly burned following early logging. The trees are usually small and of very poor quality.

In the southern half of the Lower Peninsula the principal product is sawlogs. Other products include veneer logs, piling, cooperage, posts, and fuelwood. In some localities, limited markets exist for pulpwood.

The utilization of scrub oak is limited, although in some areas it is used for pulpwood. Railroad ties and pallet stock are also produced from scrub oaks.

One of the principal problems in managing this general type of forest is regenerating the stands with a satisfactory stocking of oak reproduction after cutting. In the southern half of the Lower Peninsula, grazing has made the reproduction problem even more difficult. There is a general lack of markets for oak of low quality.

Brief descriptions of the major species of oak which have not been given previously are as follows:

Black oak usually attains a height of 60 to 80 feet with a trunk diameter of 1 to 3 feet. The crown is irregular in shape and often wide.

The leaves are usually 5 to 6 inches long and 3 to 4 inches wide, shallow or deeply lobed, the shape varying greatly. When mature the leaves are dark green and shiny on the upper surface, pale on the lower, more or less covered with down, and with conspicuous rusty brown hairs in the forks of the veins.

The fruit matures the second season. The nut is from 1/2 to 1 inch long, more or less hemispherical in shape, and from one-half to three-quarters enclosed in the thick, scaly cup. The kernel is yellow and extremely bitter.

The bark soon becomes rough and black—on old trees thick, broken by deep fissures into thick ridges, which are cross-fissured. The inner bark is bright yellow.

White oak may develop to a height of 60 to 80 feet or more with a diameter of 2 to 4 feet, and considerable clear length in the forest. Open grown trees have a deep, wide crown.

The leaves are simple, alternate, 5 to 9 inches long and about half as broad. They are deeply divided into five to nine rounded lobes, bright green above and much paler below.

The fruit is an acorn, maturing the first year, the nut being 3/4 inch long, light brown with about one-fourth enclosed in the cup. The bark is light ashy-gray, broken into thin platelike scales.

Shagbark hickory

Red maple

Wild black cherry

Black walnut

Shagbark hickory usually attains a height of 50 to 75 feet with a diameter of 2 feet. The leaves are alternate, compound, 8 to 14 inches long, with five to seven leaflets. Male and female flowers occur on the same tree. The fruit is a nut similar to the bitternut but has a thicker ridged shell and large sweet, edible kernel, and is covered with a thick husk which splits to the base.

The bark on old trunks is light gray, peeling off in long curved platelike strips, which are usually loose at the ends and attached in the middle.

Red maple is usually a medium-sized tree 40 to 60 feet high and 1 to 2 feet in diameter, but sometimes larger.

The leaves are simple, opposite, three to five lobed, but not so deeply cut as the silver maple, and doubly serrate or toothed, dull green above, whitish beneath, in autumn turning a brillian red.

The flowers appear in dense clusters in early spring before the leaves, and although small, are quite conspicuous because of their red color. The fruit consists of a pair of winged seeds or keys which fall somewhat later than those of the silver maple and are but half as large, though like those of the silver maple, they germinate at once.

The bark is smooth and light gray on young stems, and dark gray and rough on old trees.

Black cherry is a medium-sized tree, up to 70 feet high and 1 to 3 feet in diameter.

The leaves are similar to those of the chokecherry but usually more gradually tapered at the apex, thicker, with the upper surface shiny, and the teeth on the margin incurved.

The flowers are similar to those of the chokecherry and the fruit is purplish-black with dark purple juicy flesh, slightly bitter, but edible, maturing later than the chokecherry.

The bark is thin, red-brown, becoming blackish and broken into thick irregular plates. The inner bark has the flavor of bitter almonds.

Black walnut may reach a height of 100 feet with a diameter of 2 to 3 feet or more. In the open, the stem is short and the crown broad and spreading.

The alternate, compound leaves are 1 to 2 feet long, and consist of 15 to 23 leaflets which are about 3 inches long, extremely tapering at the end and toothed on the margin. The chambered pith is cream colored.

The fruit is a nut enclosed in a solid yellowish green nearly spherical husk, which does not split open even after the seed is ripe. The nut itself is hard and irregularly furrowed, and edible.

The bark is thick, dark brown, and divided rather deeply into rounded ridges.

Pin oak

Silver maple

Northern pin oak seldom exceeds a height of 50 feet or a diameter of 2 feet. The trunk is short and bears many forked branches.

The leaves are similar to those of the scarlet oak, but not so shiny above, with five to seven lobes. Late in autumn they turn yellow or pale brown, more or less blotched with purple. The acorn requires two seasons to mature, and is inclosed for one-third to one-half its length in the cap, which gradually tapers at the base.

The bark resembles that of the scarlet oak but the inner bark is pale yellow.

Lowland Hardwoods

This association includes stands on poorly drained areas where the predominating species in the overstory are red and silver maple, American and slippery elm, swamp white oak, cottonwood, basswood, and black and white ash. The stands tend to be even-aged in groups, and sometimes in their entirety where they have resulted following heavy cutting.

The principal product is sawlogs. High value veneer logs and piling are produced in limited amount. Considerable fuelwood is cut, and pulpwood is a product of currently limited but potentially expanding importance.

One of the major problems is how to remove the accumulated number of poor trees. Another problem is how to obtain seedling reproduction of desirable species after cutting. Frequent flooding and heavy vegetative competition result in conditions unfavorable to seedling establishment.

Serious overcutting in some stands and lack of desirable and needed cutting in other stands are prevalent. Mills which produce blocking and crating utilize primarily lowland hardwoods. Trees as small as 6 inches d.b.h. are utilized for these products, so that after cutting, a stand may contain only culls and a few saplings. The large number of culls should be removed to make way for better trees. Their utilization or elimination constitutes a difficult problem.

Other problems are related to the susceptibility of these stands to damage by ice, wind, fire and decay. Grazing is also a serious problem.

Principal species in this type which have not previously been described include:

Silver maple usually grows to a height of 40 to 60 feet and may reach a diameter of 3 to 4 feet. Occasional specimens may be larger.

The leaves are opposite, simple with three to five lobes, ending in long points with toothed edges, and are separated by deep angular openings, which extend nearly to the midrib. They are pale green on the upper surface and silvery white underneath.

The flowers appear in the spring before the leaves, in dense clusters, and are of a greenish yellow color. The fruit ripens in late spring, and consists of a pair of winged seeds or keys.

The bark is smooth and gray, becoming darker and furrowed, separating into long flakes.

Swamp white oak

Eastern cottonwood

Black ash

20 . Tulip tree (yellow poplar)

Swamp white oak may reach heights of 60 to over 100 feet with diameters of 2 to 3 feet or larger.

The leaves are 5 to 6 inches long, round toothed or slightly lobed, dark green and lustrous above, and pale beneath. The acorns mature in one season and grow in pairs on slender stalks 1-1/2 to 4 inches long, the nut enclosed for about one-third of its length by the cup.

The bark on small branches is smooth, later separating into large thin scales which curl back, exposing the inner bark.

Cottonwood often attains a height of 70 to 90 feet with a trunk diameter of 3 to 5 feet, forming a spreading open symmetrical crown, often dividing 20 or 30 feet from the ground into several massive limbs.

The leaves are broadly ovate or triangular pointed, square at the base, and coarse-toothed at the edges, 3 to 5 inches long, light green above and paler below. The male and female flowers occur on separate trees. The winter buds are covered with chestnut brown resinous scales.

The bark becomes ashy gray, deeply divided into broad rounded ridges.

Black ash is a medium-sized slender tree, 60 to 80 feet in height, with a diameter of 1 to 2 feet, forming in the forest a narrow crown of upright branches.

The leaves are similar to those of other ashes, but the leaflets, except the terminal one, are sessile, that is, without a stalk or stem.

The flowers are of two kinds and may be borne on the same or different trees, the male flowers in dense dark purple clusters, the female in open drooping clusters. The wing of the fruit is broader than that of the white and red ashes, with the apex distinctly notched, and completely surrounds the flattened seed bearing part.

The bark is thin, grayish, scaly, and breaks up by rubbing with the hand.

Mixed Hardwoods

This group consists of stands in the transitional zone between northern hardwoods, and the oak-hickory and similar species mixtures common in the Central States. Included in this group are upland red oak, sugar maple, ash, poplar. The stands are generally uneven aged.

Stands in this type group are located in the southern part of the Lower Peninsula, mostly on privately-owned farm lands. Individual ownerships vary from two or three to several hundred acres, with the average size holding being approximately 15 acres. This type group is widely distributed and of high economic importance.

The principal product is sawlogs. Others include veneer logs, fuelwood, some piling, and a limited amount of pulpwood. Potentially, pulpwood is a very important product from these stands, especially from improvement cuttings which are often necessary.

The principal management problems are grazing, and cutting of the better trees and leaving the poorer trees. Unwise cutting and grazing have resulted in understocked stands containing a high proportion of trees of poor quality and insufficient reproduction of desirable species. Occasionally, undercutting is also a problem, in that some stands have been insufficiently cut in the past to keep them growing vigorously. Even in such stands, however, there are too many low grade trees for good net growth.

Principal species found in this type which have not been previously described include:

Yellow poplar may grow to a very large size. Heights of 120 feet and diameters of 4 feet or more have been recorded. However, most specimens are considerably smaller.

The leaves are from 4 to 6 inches long, borne on slender long petioles. he base of the leaf is rounded while the top portion appears cut-off or shallowly notched. They are darker green above and paler beneath.

The large, greenish-yellow flowers are borne singly on the ends of twigs after the leaves have developed. They develop into a 2 to 3 inch long spindle shaped fruit which contains several seeds.

The brownish bark of the tree is furrowed into close, interlacing rounded ridges. Shallow greenish crevices separate the semiparallel ridges.

Aspen

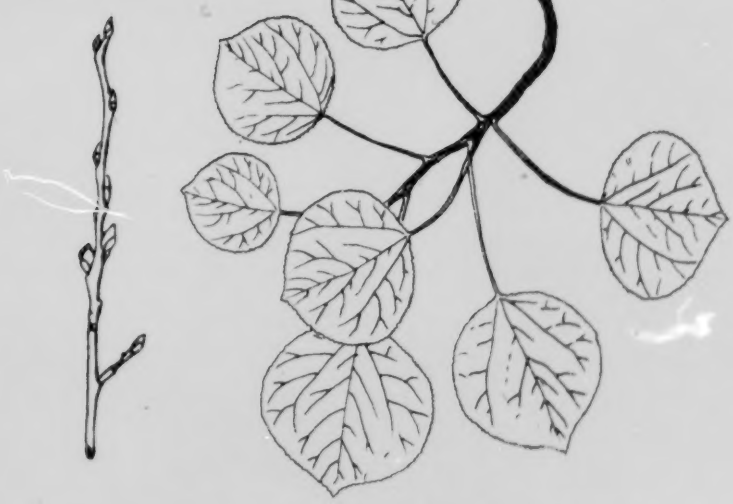
Predominant species in the aspen type are trembling (quaking) aspen and largetooth (bigtooth) aspen (both commonly called popple). Balm-of-Gilead, or balsam poplar, also occurs in stands on low ground with poor drainage, along

river bottoms, and in swamps. Aspen occurs naturally in pure stands or in mixture with most of the native conifers and other hardwoods which formerly occupied the site before cutting and fires.

Aspen stands are even-aged and constitute a forest type that originated following extensive and severe logging and fires in the past. Aspen was widely but sparsely distributed throughout Lower Michigan before logging began. It now occupies three million acres in nearly pure stands which have developed almost entirely within the past 60 years. It is the most widespread of all forest types in Michigan and is now of high economic importance.

Pulpwood is the principal product. Other products are excelsior bolts, box bolts, sawlogs, and veneer logs. Markets for aspen products have been getting progressively stronger since the early 1940s, but it has only been since 1950, when pulpwood became the principal product, that its real economic importance has developed.

The major problem in managing aspen is maintaining a pure stand in competition with other hardwoods and conifers. Aspen ordinarily regenerates satisfactorily, but the root suckers do not compete successfully when shaded by the residual stems of any species.



Trembling aspen (quaking aspen)

Bigtoothed aspen

Principal components of the aspen type include the following:

Quaking aspen is a medium-sized slender tree, usually 30 to 50 feet high, with a diameter of 10 to 20 inches, forming a loose round crown of slender branches.

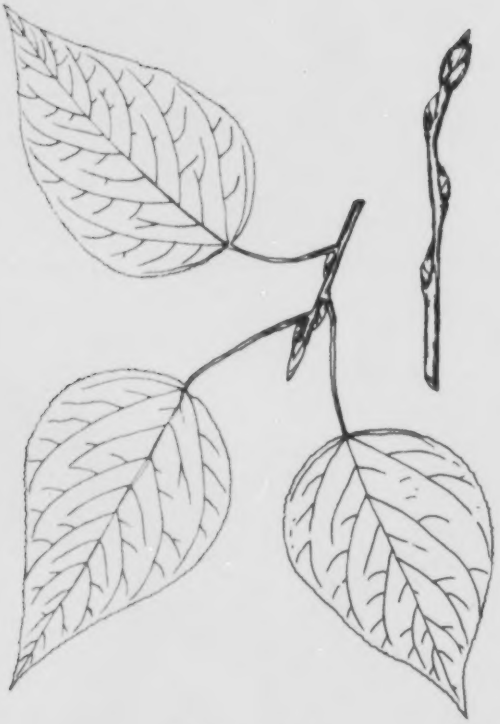
The simple alternate leaves are broadly ovate, thin, firm, finely toothed on the margin, dark green above and pale below. The petioles, or leaf stems, are slender and flattened, permitting the leaves to tremble in the slightest breeze, whence the name "quaking aspen."

The male and female flowers are found on separate trees. The fruit is a capsule 1/4 inch long, the seeds surrounded by a nap of long fine white hairs, enabling them to be blown long distances.

The bark is smooth, thin, yellowish green to nearly white, with wartlike excrescences becoming thick and fissured and almost black.

Bigtooth aspen is similar to quaking aspen but differs in the following respects: the buds are larger, but not so sharply pointed, the twigs and leaves in early spring are covered with a whitish wool which soon disappears, the leaves are usually about twice as large with prominent coarse teeth on the margins.

The bark on young trees and the upper bark on older trees is smooth and olive-green in color. The older bark is rough and furrowed.



Balsam poplar

Jack pine

Red pine

Eastern white pine

Balsam poplar attains a height of 60 to 80 feet or more with a diameter of 2 to 4 feet, forming a rather narrow open pyramidal crown of horizontal branches.

The leaves are ovate-lanceolate, 3 to 5 inches long and about half as broad, faintly scalloped and finely toothed.

Male and female flowers are on separate trees. The fruit is a capsule, borne in catkins 4 to 6 inches long, containing light brown hairy seeds. The winter buds are long-pointed, brownish, resin-coated, sticky and fragrant.

The bark is thick and grayish on old trunks, and divided into broad rounded ridges.

Jack Pine

Jack pine is the most nearly pure of the natural forest types in Michigan. Associated species include various oaks, and occasionally red pine and aspen. The stands are commonly even-aged and single-storied, or sometimes two-storied with advance reproduction under a light stocking of larger, often mature trees. The type occupies nearly a million acres in the Lower Peninsula, chiefly on the lighter sandy soils, and is of high commercial importance. The major portion of this area is on lands in federal and state ownership.

Pulpwood is the main product, but there is an increasing market for sawlogs. A minor use is for ready-cut cabin logs.

The most important problem is that of regenerating the stands at the time of the final harvest. Advance reproduction usually is inadequate and jack pine seedbed requirements are exacting. The characteristic serotinous cones of the species add to the regeneration problem.

The principal species of this type is Jack pine. Its needles are light green at first, soon becoming darker, 3/4 to 1-1/4 inches long, grow in clusters of two and fall during their second and third year. The cones are oblong-conical, strongly incurved, and often remain on the tree for years without opening until heated by forest fires, thus re-seeding the ground after fires.

The mature tree is frequently 70 feet high or occasionally higher, rarely exceeding 2 feet in diameter, though often retaining dead branches nearly to the ground. The bark of the trunk is thin, dark brown or gray, and divided into narrow connected ridges.

Red Pine

Red pine occurs naturally in mixture with white and jack pine, and as a minor species in associations with oak, birch, and aspen, and occasionally in pure stands. The soils on which it occurs range from sands to gravels and dry sandy loams. Present natural stands are usually even-aged and understocked. The majority of the area in this type at the present time is in plantations.

Plantations are either pure or mixtures of red and white pine or red and jack pine. Soils are the same as for the natural stands and plantings are usually made only on open situations because of the intolerance of the species. Plantation stands are even-aged and usually well stocked.

Red pine is distributed widely throughout Michigan, with the major portion being in federal, state, and large to medium private ownerships. It is widespread as a result of extensive plantings. Many plantations are approaching merchantable size and commercial importance.

The principal products derived from red pine at present are posts, pulpwood, cabin logs and some sawlogs. In the future, the principal product will be sawlogs, with such products as posts, pulpwood, utility poles and piling obtained primarily from thinnings. There is also a possibility that stands may be managed on a shorter rotation with pulpwood as the final crop.

A major problem is the need for releasing pine from hardwood competition—mainly aspen, oak, and other hardwoods.

The principal species, red pine has needles which are slender and flexible, dark green and lustrous, 5 to 6 inches long and grow in clusters of two, falling during the fourth or fifth season. The cones are ovate-conical, 2 to 2-1/4 inches long, and shed their seeds in early autumn, and remain on the tree till the following summer.

The mature tree is usually 80 to 90 feet or occasionally 150 feet tall, and 2 to 3 feet in diameter with an open round topped crown. In fully stocked stands it grows very tall and slender with a short crown and clean bole. The bark of the trunk on older trees is 3/4 to 1-1/2 inches thick and divided into broad flat ridges, covered by thin, loose, light, red-brown scales.

White Pine

White pine occurs in natural stands on sandy loam uplands in either pure stands or in association with red pine, jack pine, oak, aspen, red maple and cherry. The natural stands are usually even-aged and understocked.

White pine is located chiefly in the western part of the state, with the major portion being in federal, state, and large to medium private ownerships. Extensive plantations are approaching merchantable size and commercial importance at the present time.

The principal product derived from white pine is sawlogs. Other products include piling, posts, poles, pulpwood and cabin logs. The smaller products are being obtained from material removed in thinnings.

The original natural stands of white pine have been so decimated by logging and fire that the establishment of white pine on the many acres of semiopen lands now sparsely covered with unmerchantable growth of aspen, cherry, red maple and oak is a long-time proposition. Manual or machine planting is usually necessary to establish the pine and there must follow operations to release and improve the stand.

The principal species, white pine may reach a height of 200 feet and a diameter of 4 feet or more. However, most are considerably smaller than this.

The needles are 3 to 5 inches in length and occur in bundles of five, which distinguishes it from all other eastern pines. Most of the needles fall in September of the second year. The cones, or fruit, are usually 5 to 8 inches long, and require two years to mature.

The bark on young stems is thin, smooth, and green, tinged with red, becoming one to two inches thick, and divided into broad connected ridges, and dark brownish gray in color.

Swamp Conifers

Coniferous swamp stands are most frequently a mixture of black spruce, balsam fir, northern white cedar, and tamarack. Black spruce frequently occurs in pure stands over extensive areas. Balsam fir sometimes occurs in almost pure stands of scattered small patches. Occasional pure tamarack stands are found in small patches. Cedar is usually found in mixture with other species and is seldom found in pure stands. Aspen, hemlock, white pine, paper birch, mixed hardwoods, white

spruce, and balsam poplar may be found in varying amounts in the drier margins of the type. Black spruce, tamarack, and balsam fir stands generally are even-aged. If allowed to grow undisturbed, black spruce and balsam fir stands become uneven-aged. Cedar stands are inclined to be all-aged. The coniferous swamp type makes up approximately 5 percent of the timber acreage and is mostly found in the northern half of the Lower Peninsula, largely in public ownership.

Black spruce and balsam fir are primarily managed for pulpwood production. Some sawlogs are marketed from large trees and well-formed Christmas trees are produced from saplings and tops of pulpwood trees. Spruce is used for cabin logs to some extent.

Tamarack is produced in the form of pulpwood, structural timbers, sawlogs, railroad ties, fenceposts, and cabin logs. There is little general market demand for tamarack because so little has been available during the past 40 years. Tamarack is the strongest structural coniferous wood in Michigan. As present young stands reach merchantable sizes, markets can be expected to develop for products from them.

Northern white cedar

White spruce

The primary demand for cedar is in the form of fenceposts which are readily marketable. Other products of minor importance are railroad crossties, large telephone power poles, sawlogs, and bolts of varying length for specialty products

Northern white cedar at maturity is usually 50 to 60 feet high and 2 to 3 feet in diameter with a buttressed trunk and narrow compact crown. The needles are scalelike yellow-green, falling with the short lateral branchlets. The cones are 1/3 to 1/2 inch long with only 6 to 12 scales, and mature in one season. The bark is grayish to reddish brown, thin, furrowed, separating into long stringy strips.

Cedar is favored browse for deer. Where deer population is heavy, stands are seriously damaged and reproduction is prevented.

Major species in the swamp conifers type include the following:

White spruce has needles which are four-sided, incurved, with sharp tips, pale to dark bluish green in color, and 1/2 to 3/4 inches long. The cones are more cylindrical than those of the black spruce and usually 2 inches long, falling in autumn or winter of the first season.

The white spruce reaches 60 to 80 feet, rarely 100 feet, with a diameter of 2 to 2-1/2 feet. The crown is a broad-based, open pyramid, the rigid branches curving upward. Except in dense forests, the crown extends well down on the trunk. The bark is thin, separating into platelike, light gray scales more or less tinged with brown.

Black spruce

Balsam fir

Tamarack

Black spruce has needles which are four-sided and mounted in a scalelike base, 1/4 to 3/4 inch long, bluish-green, and persistent for 7 to 10 years. The cones are ovate, 1-1/2 inches long, maturing the first season, green, tinged with purple, becoming light brown at maturity, and remaining on the tree for many years.

The mature tree seldom exceeds 60 feet in height and 1 foot in diameter. It is often a stunted tree less than 30 feet high.

The crown is dense, and narrow conical in form, extending nearly to the ground, except in dense stands. The bark is thin, and broken on the surface into thin gray-brown scales.

Balsam fir is a short-lived, medium-sized tree, attaining a height of 40 to 60 feet or rarely taller and a diameter of 1 to 2 feet, with a symmetrical crown and tapering trunk.

The needles appear two-ranked, are stalkless, flattened, and 3/4 to 1-1/4 inches long, dark greenand shining above, pale beneath, and fragrant when crushed or dried.

The bark on young trees is thin, smooth, grayish, with projecting resin blisters, becoming 1/2 inch thick, roughened by irregular scales.

Tamarack has needles which are scattered singly along the leading shoots, or clustered on the short lateral branchlets, linear with blunt apex, about 1 inch long, soft and flexible, bright green, turning yellow and falling in September or October of the first year. The tamarack is the only native Michigan conifer which is not evergreen.

The cones are 1/2 to 3/4 inch long, composed of about 20 scales, maturing the first season, but persisting for a year longer. The trees reach a height of 80 to 100 feet and a diameter of 1 to 2 feet, with a broad open crown of horizontal branches. The bark of the trunk is 1/2 to 3/4 inch thick, separating into thin reddish-brown scales.

Terminology

There are several terms and concepts specific to forestry and forest pest control with which a forest pesticide applicator should be familiar.

1. All-aged or uneven-aged forest management: This type of management involves the periodic removal of individual trees from the stand while

preserving its natural appearance. Forests under this type of management theoretically contain trees of all ages. This type of management is commonly applied in eastern hardwood forest types.

2. Even-aged forest management: This type of management involves the periodic harvest of all of the trees on part of the forest at one time or in several cuttings over a short period of time to produce stands containing trees all the same or nearly the same age. This type of management is commonly used in conifer and aspen management.

3. Clearcutting: Harvest of an entire stand of trees in one cutting operation. Produces an even-aged forest stand.

4. Selection cutting: Harvest of trees from the stand either as individuals or small groups at relatively short intervals (usually 10-20 years). Produces an uneven-aged forest stand.

5. Seed-tree cutting: Harvest of a forest stand in one cut except that scattered trees are left to provide seed to establish new stand. Produces even-aged stands.

6. Rotation: The length of time in years required to establish and grow timber crops to a specified condition of maturity.

7. Timber stand improvement: The selective removal of undesirable trees from a stand to favor desirable trees. Trees removed may be undesirable because of species, form, condition, or spacing.

8. Conifer release: The application of selective phytocides to kill woody or herbaceous vegetation competing with desired conifer species.

9. Conifer: A tree belonging to the order Coniferae, usually evergreen, cone bearing, and with needlelike, awllike, or scalelike leaves such as pines, spruces, firs, and cedars. Often referred to as "softwoods."

10. Site preparation: Preparing an area for reforestation by such activities as clearing, chemical vegetation control, and plowing.

11. High-volume ground spray: Application of pesticide to low brush with power sprayer delivering enough volume to wet foliage to drip point.

12. Low-volume spray: Broadcast application of pesticide by aircraft or ground rig such as a mist blower at a rate of 30 gallons per acre or less. Foliage is not totally soaked. Aircraft application must be specified on the label.

13. Directed spray: Any application of a phytocide in which the spray is prevented from contacting the crop species by orientation of the nozzles or by shielding.

14. Tree injectors: Equipment specially designed to inject phytocides into the trunk of a tree.

15. Phytocides: Chemicals which kill plants.

16. Silvicides: Chemicals which kill woody plants.

17. Herbicides: Chemicals which kill herbaceous plants. In common usage often used interchangeably with the word phytocide.

SELF-HELP QUESTIONS ON PRINCIPAL FOREST TYPES IN MICHIGAN

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What is the predominant tree in the northern hardwood association?

2. What causes the most acute problems for northern hardwood forests in farmland and adjacent woodlands?

3. What is the principal product of lowland hardwood forests?

4. List at least four problems associated with lowland hardwood forests.

5. List at least three species included in the mixed hardwood forest association?

6. What is the most important problem for jackpine forests?

7. What will the principal product derived from red pine forests be in the future?

8. On what type of soil are white pine forests found in nature?

9. List the four most common species included in swamp conifer forests.

10. In what type or types of forest is all-aged or uneven-aged forest management commonly applied?

11. In what type or types of forest is even-aged forest management commonly applied?

12. Distinguish between clearcutting, selection cutting, and seed-tree cutting.

13. How do silvicides differ from phytocides?

FOREST INSECTS

Although thousands of insect species occur in the forest, a relatively small number of them are potentially damaging and few of these ever reach injurious levels. Nevertheless, millions of board feet are lost annually because of insect activity. Insects are undoubtedly one of the most destructive components of the forest ecosystem.

Insects may affect forests directly, through increased tree mortality, or indirectly, by growth reduction and a general decline in tree vigor. These latter effects dispose trees to further damage from insects and/or diseases and eventually lead to tree mortality.

The importance and the extent of insect damage may vary according to: the size of the particular insect population, the location and type of feeding damage, the time of year, and the importance of the damaged area to the survival of the tree. It is therefore necessary for all those concerned with forest insect control to be familiar with the life histories, hosts, and feeding damage of the major insect pests in their particular region.

FOREST INSECT AND MITE CONTROL

Management decisions involving forest insect pests should be based on thorough consideration of ecological and economic factors. The insect pest in question, its biology and type of damage and the value of the forest resource affected are some of these factors that indicate which control strategies and methods, if any, should be used.

In forest situations where low value products are being produced, a certain degree of natural control may be economically acceptable. However, insect or mite control in a forested recreational or other special-use area may be justified because of the high value it has for consumer use.

In general, control decisions represent a compromise between the value of the forest, the extent of damage, and the relative effectiveness and cost

of the control and its impact on the environment.

DISTINGUISHING INSECTS AND MITES

Insects

Adult insects possess several features which readily distinguish them from other small animals in the forest (Table I). These characteristics are: (1) a body divided into three regions—a head, thorax and abdomen; (2) wings; and (3) three pairs of legs.

However, most damage to trees is done not by the easily recognized adults, but by the larval or immature stages of the insect. A familiarity with the immature stages and their development is helpful in determining what is responsible for any observed tree damage. Two common types of insect development are complete and gradual metamorphosis (Table II). Young of insects with gradual metamorphosis are called nymphs and are similar in appearance to the adults. The nymphs differ from adults principally in size and the lack of wings. They utilize the same food material as the adults and cause the same kind of damage (see Table II for examples).

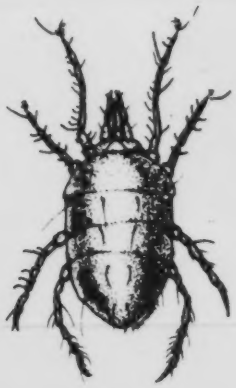
Immature forms of insects that exhibit complete metamorphosis differ from adults in several ways: (1) they are dissimilar in appearance, (2) they occupy different habitats, and (3) they utilize different food sources. The young are more or less wormlike and are called larvae (larva singular). Insect larvae generally have chewing mouth parts and may or may not have thoracic legs or leglike appendages (called prolegs) on the abdomen. Larvae increase in size by a process called molting (shedding their skin). When the last instar (stage) is reached, the larva transforms into a stage called the pupa. The pupal stage is usually an inactive or resting stage and no feeding takes place. Pupae may be covered by a cocoon or other protective material such as plant debris or soi. Many insects overwinter in this stage. For examples of insects with complete metamorphosis see Table II.

TABLE I. The major groups of insects and mites that are of economic importance in forests.

Kind of Animal	Common Name	Scientific Classification	Key Characteristics
Insects	Aphids	Homoptera	Pair of cornicles (tubes) on abdomen
	Beetles	Coleoptera	First pair of wings hard
	Flies	Diptera	One pair of wings
	Moths	Lepidoptera	Body and wings covered with scales
	Plant bugs	Hemiptera	Prominent beak, front half of wing hard
	Sawflies	Hymenoptera	Abdomen not constricted at base, first pair of wings larger than second
	Scales	Homoptera	Body covered with a scale or waxy material
	Termites	Isoptera	Both pairs of wings same size
	Wasps	Hymenoptera	Abdomen constricted at base, first pair of wings larger than second
Mites	Spider mites	Tetranychidae	6-8 legs
	Eriophyids	Eriophyioidae	4 legs

Table II. Insect development or metamorphosis.

Type of Metamorphosis	Life Stages	Examples
Gradual	Egg Nymph Adult	Aphids, plant bugs leafhoppers, scales
Complete	Egg Larva Pupa Adult	Beetles, sawflies moths, flies, wasps



Mites

Mites are not insects but rather a type of spider (Arachnida). Mites differ from insects in two major ways: mites (1) possess four pairs of legs and (2) lack wings. Their development is similar to the gradual metamorphosis of insects in that the immature forms resemble the adults and utilize the same food source. However, when the young mite hatches from the egg, it only has six legs and is often called a larva. It then molts to a nymph stage which has eight legs. The life cycle of a typical spider mite is shown above.

CATEGORIES OF FOREST INSECT PESTS

Forest insect pests may be conveniently placed into categories based on their mode of feeding and/or damage (Table III). Each of these groups will be discussed separately and the discussion will include information on biology, type of injury, controls, and other general characteristics. One or more examples from each category will be treated in depth as representative for that group.

Leaf and needle feeders

These are insects which feed on leaves, buds, and sometimes flowers of both hardwood and coniferous trees. The most destructive defoliators are larvae of sawflies, moths and a few flies and beetles. These larvae possess chewing mouthparts and may cause defoliation by mining needles or leaves, skeletonizing the leaves by consuming only the tissue between the veins, or eating the entire leaf. Although deciduous trees can withstand several years of complete defoliation, conifers may die after one total defoliation. Several important insect defoliators of forests in Michigan are discussed below.

Forest tent caterpillar *(Malacosoma disstria)*. This moth is perhaps one of the most important defoliators of forest trees in Michigan. It occurs in epidemic numbers but at irregular intervals. Normally, these outbreaks last from three to six years and then subside because of starvation or natural control factors such as parasites and predators.

Trees attacked: Poplar, sugar maple, basswood, birch, alder, red oak and willow are preferred.

Type of injury: During early to mid-June, infested trees may be completely stripped of their foliage. While new leaves are produced later in the summer, trees are weakened and their growth reduced. Tree mortality can occur following four to five years of complete defoliation, but usually only branches and tops of trees are killed.

How to identify: Young caterpillars are uniformly black, later turning brown with a pale blue band along each side. Each larva has a row of white, keyhole-shaped dots along its back.

TABLE III. Major groups of insects and mites categorized according to their type of feeding damage.

Category	Insects, Mites	Type of Damage	Impact on Tree
Leaf or needle feeders	Larvae of moths, sawflies, and some beetles	Leaf or needle tissue consumed	Loss of leaves stops photosynthesis, weakens tree; mortality could result if repeated often
Bud and shoot feeders	Larvae of moths and beetles	Terminal growth of buds, shoots and twigs consumed or destroyed	Tree deformity (forking) results; repeated tip damage may cause tree mortality.
Sap feeders	Aphids, mites, scales, plant bugs	Foliage, stem, twig or branch tissue is pierced and sap and chlorophyll are sucked from the tree	May reduce tree vigor and growth; honeydew buildup can cause a fungus problem; seldom kills tree
Seed and cone feeders	Larvae of beetles, moths and some wasps	Developing cones or seeds are destroyed	Reduces reproduction potential of tree
Gall makers	Aphids, mites, larvae of flies and wasps	Produce galls or irregular growths on leaves, twigs, limbs or trunks	Causes tree deformity; rarely results in tree mortality
Wood borers	Beetle larvae and adults, termites	Larvae tunnel into sapwood and heartwood	Reduces value of timber; permits secondary invasion by fungi; seldom results in tree mortality
Bark beetles	Beetle larvae and adults	Larvae and adults tunnel into the soft tissue and phloem of trunks and branches	The girdling effect of the tunneling results in tree mortality
Root feeders	Beetle larvae	Larvae attack and feed on roots or lower bark	Severely damaged roots may lead to tree mortality especially in small seedlings

Life history: Egg masses are deposited on twigs by adult moths during July. These eggs overwinter and begin to hatch in late April. Groups of young caterpillars feed on buds and later leaves, and unlike the eastern tent caterpillar, the forest tent caterpillar does not produce a tent or nest. However, they may congregate in masses on tree trunks when the weather is unfavorable. By early July, the larvae mature and search for places to pupate. Upon locating a suitable pupation site, they spin a pale yellow mass of threads, two inches long, on leaves, fenceposts or buildings, and pupate inside it. Adults emerge two weeks later, mate and lay approximately 150 eggs in a mass on the twigs of the host trees. There is one generation each year.

Control: Chemical—Larvae of the forest tent caterpillar can be controlled by aircraft or ground application of insecticides. Aircraft is preferred to ground equipment where large areas are to be treated since chemicals can be applied more rapidly, and to areas inaccessible to ground sprayers. Sprays should be applied in the spring after all eggs have hatched but before extensive tree damage occurs. In addition to the area to be protected, a buffer strip of 400-500 feet should also be sprayed around the protected area to prevent invasion by migrating caterpillars.

Biological—The sarcophagid fly, *Sarcophaga aldrichi*, is the most numerous natural enemy of the forest tent caterpillar. The adults (gray flies about 3/8 inches long) deposit young maggots on the caterpillar pupae. Within 10-14 days, they destroy the pupae and reduce the number of moths which emerge to lay eggs. This parasitic fly may become extremely numerous and bothersome since it is attracted to human skin. However, it does not bite and is merely a nuisance.

Gypsy moth (*Lymantria dispar*) is a major pest in over 200,000 square miles of forest in the northeastern United States. Current estimates indicate that approximately 600,000 acres of Michigan forests are lightly infested with this moth. However, it has not been numerous enough to cause severe defoliation problems in Michigan. Nevertheless, once established, the potential impact of this pest on Michigan forest could be devastating. For this reason, the Michigan Department of Agriculture (MDA) and the USDA's Animal and Plant Health Inspection Service are working to contain and suppress the spread of gypsy moth. In 1976, the MDA and the Michigan Forest Service supervised the spraying of approximately 16,000 acres of forests to control this moth.

It is important that you understand some basic facts about this insect, its biology, and how to recognize it so that newly established infestations can be located and destroyed.

Trees attacked: Apple, alder, basswood, hawthorn, oaks, some poplars, and willows are preferred. Elms, black gum hickories, maples and sassafrass are less preferred hosts but are frequently attacked. Occasional hosts include beech, hemlock, white cedar, pines and spruces.

Type of injury: Two or more years of complete defoliation by gypsy moth caterpillars may kill many trees. Of course, factors such as tree type, age, growing site, amount of defoliation and environmental conditions will influence the impact on the tree.

How to identify: Larvae are hairy, about 1-1/2 to 2 inches long with the first five body segments blue and the last six brick-red. Female moths are white with a buff or yellowish abdomen and a wingspread of two inches. Male moths are dark brown with a wingspread of 1-1/2 inches.

Life Cycle: The gypsy moth overwinters as masses of up to 1,000 eggs covered with buff or yellowish hairs from the abdomen of the female. Masses, about 1-1/2 inches long and 3/4 inches wide, are laid on the bark of trees, under stones, in hollow trees, on buildings or any other solid material affording protection from the weather. During late April or early May, eggs hatch and young larvae move to the tops of trees where they spin down on silken threads allowing air currents to blow them considerable distances. This is the principal means of natural dissemination. Newly hatched larvae feed on the leaf bases, then leaf surfaces where they chew holes in the leaves. Older larvae feed inward from the leaf edges completely consuming the leaves, leaving only midribs and larger veins. Larvae mature during late June and pupate. Pupae are normally located on the bark of trees or in a place protected from the weather. Adults emerge about mid-July; both males and females are winged but only the males can fly. Females lay their eggs near the pupal case from which they emerged. Males find females by means of a pheromone (sex lure produced by the female). This scent or odor, which attracts males up to 3/4 of a mile, has been chemically duplicated. This chemical, known as Displarlure, is used to bait sticky traps to detect new infestations, or determine the extent of old ones, by trapping males.

Control: Chemical--Thus far, chemical control programs for gypsy moth in Michigan forests have been directed by the MDA. Controls for gypsy moths on private land have not yet been considered. Past experience in the eastern United States indicates several years are required for severe populations to develop. In the meantime, research is continuing on the gypsy moth by Michigan State University and the USDA. More sensitive methods of detection and survey are being developed.

Biological--Studies to assess the value of introduced biological control agents as well as parasites and predators native to Michigan are underway. In the northeast, limited success has been achieved using a virus and a bacterial disease. If you discover what you regard as a life stage of the gypsy moth, please contact your county Extension agricultural agent or Michigan Department of Agriculture Inspector.

Spruce budworm (*Choristoneura fumiferana*) is the most widely distributed destructive forest insect in North America. Severe outbreaks have occurred in the northeastern spruce-fir forests of the United States and Canada at irregular intervals during the last 150 years. Millions of acres of timber have been killed where no control measures were undertaken. The Upper Peninsula of Michigan has experienced moderate damage from this insect in recent years.

Trees attacked: Balsam fir is the preferred host but white, red and black spruce, pine, larch and hemlock are frequently attacked.

Tree Injury: Light to moderate infestations result in partial loss of the new foliage, especially in the upper portion of the tree crown. Partially consumed needles on the webbed branch tips turn bright reddish-brown in midsummer. Heavy populations can completely consume the new foliage. In true firs, tree mortality ensues after five years of successive defoliations.

How to identify: Larvae are dusky colored on their upper surface, with two pairs of yellowish spots on each body segment. Their underside is a light greenish yellow. Both the head capsule, and part of the prothoracic shield (top portion of first body segment behind head) are dark brown.

Life cycle: The adult moth of the spruce budworm can be seen from early June through August. They have a wingspread of about 1 inch or 22 to 27 mm. The wings are mottled gray. After mating, females lay eggs on needles, usually in the upper branches.

Eggs hatch in about 10 days. The tiny larva (worm) then feeds a short time before finding an overwintering site.

In the spring, the larvae emerge and start feeding. They first bore into staminate flowers or old needles, but soon move to expanding vegetative buds. After the buds burst open, they start feeding on the tender young needles. When the larvae are about half-grown, they fasten themselves to a few tender twig tips and spin a thread to form a nest. Needles stuck together by a white web may be seen by an observant person. Pupation takes place in early July in these nests, and in about 10 days, the adult moths emerge. There is one generation each year.

Control: Aircraft application is the preferred method for treating large forested areas for spruce budworm. Sprays should be applied when larvae are in the third and fourth instars. A ground mist blower application is recommended for control and foliar protection of high value trees from early instars of the spruce budworm.

Bud or Shoot Feeders

These insects, mostly larvae of beetles (especially weevils) and moths, feed in the terminal growth (twigs, buds and shoots) of trees. They deposit their eggs on both terminal and lateral shoots. Upon hatching, the young larvae bore into the shoot pith, eventually killing it. The occurrence of dead, flagging shoots or buds is characteristic of borer damage. Injury of this type to young shoots or leaders causes tree deformities, such as forking, which reduce the value of the tree for timber. Moreover, seedlings and saplings are extremely vulnerable to damage from these insects, as repeated tip injury often leads to tree mortality. However, terminal damage in more mature trees is usually not of importance. Since most of these moths attack only shoots within a few feet of the ground, a tree used for timber may outgrow this susceptible height stage within a few years. However, weevils will attack taller trees causing deformed trunks in later years.

Both of these insect groups cause serious damage to Christmas tree plantations in Michigan.

Eastern pineshoot borer (*Eucosma gloriola):* This moth occurs throughout the natural range of white pine. Although it is an infrequent problem in natural stands, it is often abundant in poorly managed plantations or wherever a closed crown canopy is absent.

Trees attacked: This insect favors Scotch, jack and white pines but may also injure Austrian, red, and pitch pines as well as white spruce and Douglas fir.

Type of injury: Damage is caused by larval feeding and tunneling in the pith of new lateral or leader (terminal shoots. Heaviest attacks usually occur in lateral shoots of the upper part of the tree. Mined shoots wilt and turn red in the summer; the weakened shoots may drop or break off at right angles and die. This latter occurrence is diagnostic of shoot borer.

How to identify: Adults are small coppery moths with a wing expanse of 5/8 inch. Larvae have a dirty white color with brownish-yellow heads and when mature are about 3/4 inch long.

Life history: Adult moths emerge from overwintering cocoons in early May and lay eggs on twigs or needle sheaths. Egg hatch occurs in 10-15 days and the young larvae bore into the center of the shoot where they feed until early August. The mature larva chews a hole to the outside and drops to the ground where it pupates in soil or litter. There is only one generation of this moth each year.

Control: Large-scale chemical control measures for this moth have been relatively unsuccessful or too costly. For ornamental plantings, or small stands, hand pruning of damaged shoots while the larvae are still present may be the best control technique.

White pine weevil (*Pissodes strobi*): This is the most important pest limiting the production of timber from eastern white pine. The white pine weevil not only causes a reduction in recoverable timber volume, but degrades the lumber present in the remaining volume. It occurs throughout the range of white pine in eastern North America.

Trees attacked: All pine and spruce species are damaged by this insect but eastern white pine (*Pinus strobus*) is the preferred host.

Type of injury: A copious resin flow results from adult feeding and oviposition punctures in the terminal leader. The inner bark and cambium is girdled by larval tunneling and the top of the whorl is killed.

How to identify: The adult weevil, about 1/4 inch long, is brownish with white spots scattered over the body. The mouthparts are formed into a curved snout 1/16 inch long. The larva is curved, white, and has a brown head capsule. Both adults and larvae may be found under the bark of damaged leaders.

Life history: Adult weevils overwinter in litter under infested trees and become active when air temperatures reach 50-55°F. in the spring (usually the last two weeks of April in Michigan). During the initial week of activity, the adults feed on the upper part of the leader, and mate. Eggs are deposited in the feeding punctures on the leader for the next month or more. Larvae hatch after two weeks and tunnel into the leader where they feed on the inner bark and cambium, killing the leader of the previous year. During this time, the current year's growth starts but the new leader soon droops over producing the symptom known as "shepherd's crook." Thus, the present and previous year's growth are destroyed.

After approximately six weeks of feeding, the mature larvae construct pupal chambers in the wood or pith. Adults emerge two weeks later (mid-August to September) and feed on twigs prior to overwintering.

Other bud or shoot feeders which may be a problem in Michigan include the Nantucket pine tipmoth, the pine candle moth and the Jack pine tip beetle.

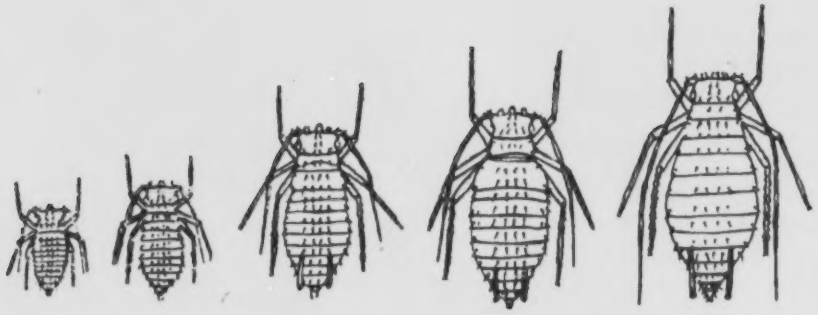
Control: When weevil populations are low, infested terminals in plantations or forest nurseries can be hand-pruned and burned by mid-July. If populations are heavy, trees can be treated chemically at three to four year intervals until they are over 30 feet tall. Effective control has been obtained with the application of a residual stomach poison to leaders in the spring when adults first emerge. However, control of this insect in large forest stands is seldom justified.

Sap Feeders:

Insects which utilize sap (or plant juice) as a food source are equipped with sucking mouthparts which are capable of piercing plant tissue and sucking fluid from individual cells or from the conducting vessels (phloem).

Pests in this category include aphids, scales, plant bugs, spittle bugs and mites. They seldom kill the tree but may reduce its vigor and slow its growth.

Control: Sucking insect damage to forests is generally not serious enough to require control procedures. The balsam wooly aphid is an exception. Tree plantations are frequently treated chemically for control of some sucking pests. Contact poisons are used as sprays but coverage is seldom complete, especially for insects or mites which feed on lower leaf surfaces. Systematic insecticides may take longer but are more effective, especially for mites.



Aphids. These soft-bodied, usually pear-shaped sucking insects nearly always with a pair of cornicles (tubes) near the tip of the abdomen. There are winged and wingless forms, both of which can occur on the same plant. They are often found on stems, leaves, branches, and flowers of many trees. Aphids discharge a clear watery liquid, called honeydew, from their anus. This sticky substance may coat plant foliage and give rise to a sooty fungus problem. Ants are often attracted to this substance which they utilize for food.

Trees attacked: All deciduous and coniferous trees are subject to attack by aphids.

Type of injury: Plant juices are sucked from branches, stems, foliage or flowers. This feeding may cause galls to form, leaf injury, leaf curl, leaf drop, or leaf discoloration. Gum may ooze from feeding wounds. Sooty mold fungus may grow on the honeydew.

How to identify: Pear-shaped bodies up to 1/4 inch long with cornicles at abdomen tip, winged or wingless, color is variable, usually long antennae.

Life History: Aphids generally overwinter as eggs which hatch in the spring into wingless females. These females (sometimes called stem mothers) reproduce parthenogenetically (without fertilization) and give birth to living young rather than eggs. Two or more generations of wingless females may be produced but eventually a winged generation appears and usually migrates to a different food plant. The winged females also reproduce parthenogenetically giving birth to living nymphs. At the end of the summer, the winged form returns to the original food plant where a generation of males and females appear and mating takes place. Females lay eggs which then pass the winter.

Control: See control for sap feeding insects.

Scales: These insects attack a wide variety of both deciduous and coniferous trees and when infestations are heavy, plant injury (loss of sap) can be severe. Females are wingless and usually legless while males are winged but lack mouth-parts and thus do not feed. Active first instar nymphs, called crawlers, possess both legs and antennae. However, when the crawler molts to the next nymphal stage, legs and antennae are lost. The nymph becomes sessile (not free to move) and secretes a waxy or scalelike covering over its body. In the armoured scales, the covering is usually separate from the body while soft scales are either bare or intimately associated with this waxy covering.

Pine tortoise scale (*Toumeyella numismaticum*). This scale was named because its hard cover resembles the shell of a tortoise. It often attains populations large enough tocause serious damage and even tree mortality.

Trees attacked: Jack pine is the primary host but it also attacks Scots, Austrian, and sometimes red pine.

Type of injury: The extensive loss of plant sap reduces tree vigor, often killing branches of entire trees. Black sooty fungus may accumulate on the honeydew which further disfigures the tree.

How to identify: Immobile oval chestnut brown insects, about 1/4 inch long near the tips of branches. A conspicuous black sooty fungus may be present.

Life history: The pine tortoise scale has one brood each year. Winter is passed by immature females in protected places on the rough bark of the twigs. Beginning the third week of June each female lays 1,000 or more eggs beneath its body. These hatch in a few hours and the reddish crawlers exit from beneath the mother scale and migrate to the terminal branches. In late August females mature, mate with the winged shortlived males, and continue to feed until cold weater occurs.

Control: See control for sap feeding insects.

Mites. Spider mites are the major mite pests of forests. They are widely distributed throughout the United States and Canada. Spider mite outbreaks have been recorded over large forested areas frequently during periods of drought. Nursery stock and recently planted trees are especially vulnerable to mite injury. Heavily infested foliage can be discolored, disfigured or killed from mite feeding injury.

Trees attacked: Most deciduous and coniferous trees of North America.

Type of injury: Plant sap containing chlorophyll is sucked from leaves or needles reducing plant vigor.

How to identify: Active spider mites range in color from yellow, green, to red and with the use of a hand lens can be seen moving about on foliage. Damaged leaves or needles become yellow to bronze in color due to the loss of chlorophyll. Small dark specs of mite frass and silken webbing may be present on the leaves.

Life history: Mites may overwinter as eggs or adults on twigs, bark, or at the base of conifer needles. Many generations can occur each summer giving rise to large populations on any given tree. The larvae have only six legs while the nymphs and adults possess eight. All stages feed on plant tissue, usually on the underside of the leaves.

Control: See control for sap feeding insects.

Seed and Cone Feeders

Insects which destroy developing cones, seeds or flowers include small wasps, and the larvae of moths and scolytid beetles. These pests have their greatest impact in seed orchards where crops have been managed for years at great expense. The damage generally occurs when developing larvae bore through the seed coat and feed on the endosperm.

Control: Seed and cone insects can be effectively controlled with systemic insecticides, when feasible.

White pine cone beetle (*Conopthorus coniperda*). This scolytid beetle is the most destructive pest of white pine seeds. Entire seed crops in many stands have been destroyed by this insect.

Trees attacked: Eastern white pine.

Type of injury: Adults and larvae tunnel through cones; larval feeding destroys seed and cone tissue.

How to identify: Adults are shiny black beetles 1/4 inch long. Larvae are white and somewhat smaller than the adults. Both can be found in the infested cones.

Life history: Adults overwinter in infested cones on the ground. In the spring, the adult female bores into second year cones on the tree and lays eggs. Developing larvae tunnel through the cone feeding on seed and other tissue. In late July they pupate in cells at the end of the tunnels. Infested cones die and fall to the ground in a few weeks. Some adults may emerge in the fall and feed on first year conelets but the majority wait until the next spring to emerge.

Other insects which may effect seeds or cones are: red pine flower moth, red pine cone beetle, and various coneworms (moths).

Gall Makers

Insect galls are abnormal plant growths on leaves, twigs, or branches caused by either mechanical or chemical stimulation from insects. Insect larvae utilize galls for protection while they bud on plant tissue or suck plant sap. Damage to forest trees from gall makers is negligible. However, in nurseries and plantations, certain gall makers are problems as they may stunt or disfigure young trees. Wasps, aphids, flies, weevils, and mites are some of the organisms which can produce galls.

Cooley spruce gall aphid (*Chermes cooleyi*). This is a common gall maker on spruce in Michigan. It is primarily a problem in nurseries, Christmas tree plantations, and on park or other ornamental trees.

Trees attacked: Colorado blue, Engleman. Sitka, and big cone spruce. An alternate host is Douglas fir.

Type of injury: These aphids suck plant sap from needles, causing galls to form. Some of the injured twigs may die.

How to identify: Elongated pineapple or conelike galls, one to two inches long, are located at the tip of new twigs.

Life history: Nymphs overwinter at the base of spruce in Douglas fir buds. In the spring, these nymphs mature and lay eggs. The eggs hatch and the young feed on the base of new spruce needles, causing them to swell and form galls. In July or August, the galls open, and some of the escaping aphids fly to Douglas fir where they lay eggs on needles. The eggs hatch and the nymphs overwinter on this tree. The next summer these aphids either continue to live on Douglas fir or fly back to spruce. Cooley spruce gall aphid can also live continuously on spruce.

Control: Contact or systemic insecticides have been effective in controlling these pests when applied in the fall to control the nymphs. When feasible, galls can be removed by hand before they open in July, making chemical treatment unnecessary.

Other gall makers freuently found in Michigan include the eastern spruce gall aphid, eriophyd mites (maple bladder galls, crimson erineum mites), oak-apple gall maker (wasps) and many others.

Wood Borers

Wood boring insects are generally considered secondary pests in that they attack dying or recently dead trees or those weakened by disease, drought, injury, or defoliation. Moreover, borers are actually beneficial in a healthy forest because they hasten the return of dead wood to the soil humus. However, forest losses due to wood boring insects may be as great as those caused by any other group of pests. Felled timber and damaged or decayed future wood products are made useless because of wood borer tunneling. Often, these tunnels allow fungi to gain entrance to heart and sapwood and produce stains which mar the utility and appearance of the products. The majority of wood borers are larvae of beetles (flat-headed and round-headed borers) but there are several important wood boring caterpillars (moths). Termites and powder post beetles may also attack dry wood on the forest floor.

Control: The best control for these insects is to remove overmature, diseased, dying, or dead trees and felled timber from the forest as soon as possible.

White-spotted sawyer (*Monochamus scutellatus*). This roundheaded borer commonly occurs in Canada and the northeastern United States westward to the Great Lakes area. The larvae are called "sawyers" because of the loud noise they make while feeding. This species and other members of the genus *Monochamus* often cause heavy losses in windthrown or firekilled timber, in sawlogs left too long in the woods before milling and in improperly handled pulpwood.

Trees attacked: White pine is preferred but other hosts include red and jack pines, balsam fir, white, black and red spruce, and larch.

Type of injury: The wood surface is scored by the shallow tunnels or galleries of the young larvae; heartwood is damaged by the extensive tunnels of older larvae.

How to identify: Adult beetles are oblongshaped and vary in length from 3/4 to 1 inch. The male is completely black except for a small white spot located toward the end of its back. The females are also black but have their back mottled with white spots. The antennae (feelers) but may be longer than the adult's entire body. Larvae are fleshy, thin-skinned, white to yellowish in color, and cylindrical in shape. Full-grown larvae may be up to 2 inches long.

Life history: Adults emerge through circular holes in the bark in late spring or early summer. They lay their eggs in slits cut in the bark, preferabley near old branch scars or in buckled areas on logs, pulpwood and recently killed trees. Young larvae feed on the inner bark, cambium, and outer sapwood forming shallow galleries and filling them with coarse fibrous borings and frass. Later in the summer, the larvae tunnel deeper into the wood to overwinter. The larvae continue to develop the second summer—two years being required to complete the life cycle in the Great Lakes area and Canada.

Control: Sawlog damage can be prevented by cutting and removing timber from the woods between September and mid-to-late June. Pulpwood damage can be diminished by piling it in the shade of standing trees or covering piles with layers of slash, one to two feet thick. These types of cultural and sanitary management are control techniques which are very effective and generally less costly than using chemical methods.

Bark Beetles

Bark beetles comprise one of the most destructive groups of forest insect pests in North America. Over 4.5 billion board feet of saw timber are killed on an average year by bark beetles. This represents about 90 percent of all insect-induced mortality in our forests.

This group is composed of beetles belonging to the family Scolytidae and can be divided into three groups: (1) true bark beetles, which mine between the bark and wood of twigs, branches, trunk and roots; (2) wood-boring bark beetles, which mine directly in the wood, and (3) ambrosia beetles which bore deep holes into the sapwood and feed entirely on fungi which grows on the tunnel walls. The larvae and/or adults "engrave" (mine treat) the soft phloem tissue which girdles and kills the tree. Also, a blue stain fungus may be introduced by the beetles which leads to tree mortality. Since there are many different species of bark beetles with varying life histories, the following discussion presents a generalized account of bark beetle biology and damage.

Trees attacked: Most species of deciduous and coniferous trees.

Type of injury: The tunneling of adults and larvae destroy the food (phloem) and water (xylem) carrying vessels of the tree often killing it in one or two years.

How to identify: Mature larvae are 1/8 to 3/8 inches long, with white, legless, curved bodies and a reddish-brown to black head capsule. Adults are 1/16 to 3/8 inches long and vary from brown to reddish-brown to black in color. Small round holes are present in the outer bark of infested trees. The area beneath the bark is grooved (engraved) by numerous designs. From a larger central groove (or tunnel), smaller grooves run at right angles through the inner bark.

Life history: Adults in the spring and immediately search for new host material, either standing trees, felled timber, or dead logs or branches. Females are the first to attack, constructing entrance tunnels through the bark to the phloem or wood. If the tree cannot resist the initial beetle attack, the females release a pheromone (chemical attractant) which guides thousands of male and female beetles to the host tree. The beetles then mate and bore egg galleries into the phloem or inner bark tissues. Eggs hatch in these galleries and young larvae bore new tunnels at right angles to the main one. The mining of the tree's phloem layer by hundreds of larvae girdles the tree. Winter is spent in the egg, larval or adult stage. Examples of bark beetles which occur in Michigan include: the ted turpentine beetle, eastern spruce beetle, easstern larch beetle, the pine engraver, and striped ambrosia beetle.

Control: Many direct-attack methods have traditionally been used to control bark beetles. These included felling, burning, or ground spraying by hand or power equipment. Buildup of beetle populations can be prevented by sanitation logging or other salvage operations.

Many natural factors to keep bark beetle populations in check—parasites and predators and low winter temperatures, to name a few.

The use of pheromones or attractants to trap beetles before they damage timber is still in the experimental stage, but it does have promise.

Root Feeders

This group is largely composed of beetles (white grubs, weevils, wire worms) and some termites. The primary impact of these insects is on forest nurseries where young seedlings are especially vulnerable to root injury.

Pine root collar weevil (*Hylobius radicis*). This insect has caused extensive mortality of pine in plantations and forest nurseries in southern Canada and the northern United States.

Trees attacked: Austrian, eastern white, pitch, jack, Scots, red, and mugho pine.

Type of injury: Larvae tunnel into the bark wood at the base of the trunk and in bases of large roots below the ground line. The cambium and phloem tissues are destroyed by this tunneling. Flows of resin at feeding points form a heavy layer of pitch and soil around the root collar.

How to identify: Mature larvae are 1/2 inch long with white, legless bodies and brown head capsules. The adults, 3/8 to 1/2 inch long, are dark reddish brown to black with irregular patches of white to yellow hairlike scales on the back.

Life history: The weevil may overwinter as a larva, pupa, or adult, and eggs are deposited from early May to late September. Larvae of various sizes can be found throughout the summer tunneling in the inner bark at the root collar. Mature larvae pupate in earthen cells in the surrounding soil from June to September. Adults emerge from August to October but do little egg laying before entering the soil to overwinter. The adults also feed on the inner bark at the base of the tree and may survive for as long as two years.

Control: These insects may be controlled by spraying when adults are actively feeding. Often the application of a soil insecticide before planting or seeding is effective as is sipping seedling roots prior to setting out.

Other root feeders which may be a problem in Michigan include the strawberry root weevil, white grubs of the genus *Phyllophaga*, oak weevils, and termites.

SELF-HELP QUESTIONS ON FOREST INSECTS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List at least 3 factors affecting the importance and extent of insect damage.

2. List four factors that must be considered before making a control decision.

3. Is most damage to trees done by the adult insect?

4. How do mites differ from insects?

5. Is terminal damage from bud or shoot feeders important in mature trees?

6. List four types of insects that are sap feeders.

7. When does damage from seed and cone feeders generally occur?

8. Do gall makers damage forest trees significantly?

9. Are wood borers considered primary or secondary pests?

10. Do true bark beetles bore deep holes into the sapwood?

11. Are root feeders more injurious to seedlings or mature trees?

FOREST DISEASES

There are several categories of forest diseases: however, few of these are successfully treated with fungicides. The cankers, rusts, and wilt diseases are the most important in terms of losses to future forest production. Nearly every tree of importance in forestry has been found with one of these types of diseases. Tree diseases, with a few exceptions, have not caused the widespread death and destruction as have outbreaks of insects. Also, the causal agent to tree diseases is often not readily found by casual inspection of an unthrift tree. Death of trees by disease is often attributed to other factors such as old age, and drought.

Diseases are generally separated into three categories based on the part of the plant where they are found.

1. Root and soilborne diseases--These may be controlled by fungicide drenches, fumigation, crop rotation, and other cultural methods.
2. Stem and branch diseases--These may be treated with fungicide sprays, pruning, and selective cutting.
3. Foliage diseases--These may be treated with fungicide sprays.

Root and soilborne diseases are seldom controlled by fumigation in a forest situation. The costs of materials and labor seldom justify the results. In most forested conditions there is ample variety in species distribution to prohibit rapid spread of root and soilborne diseases. An exception may be in plantation production where a single species is grown. Here, a soil fumigation barrier, trenching, or selective removal of certain trees may be used to stop spread of serious root and soilborne diseases.

Nurseries often use fumigation to control weeds, and disease control is a secondary benefit. However, in some cases disease control is the primary purpose of fumigation. Soil fumigation is also used to control nematodes in some forest nurseries. A disadvantage of soil fumigation is the possible elimination of beneficial mycorrhizal fungi which most trees need for optimum growth. Hence, it is important for nursery managers to know their pest and soilborne disease problems, and weigh the benefits of fumigation against the reduced growth that may occur if mycorrhizal fungi are eliminated. Proper management of organic matter, moisture, and nutrients in nursery soils will often eliminate the need for fumigation.

Stem and branch diseases, if they are severe, can be managed by selective cutting and pruning in forest stands. This practice is used where recreational or potentially high-value timber justifies the costs of such operations. In special instances, such as black walnut trees grown for veneer, fungicide sprays to reduce damage may be justified. Beneficial cost analysis should be used to determine the feasibility of spraying.

Fungicides are often used on stem and branch diseases in nursery and Christmas tree production. Other methods of disease control often found in intensive culture include weed control (to eliminate one host of a rust) and pruning or selective cutting of diseased plants. It is important to know what disease is present, the life cycle of the disease, and which method will work best to control it.

Foliage diseases are seldom controlled in a forest situation; however, as with stem and branch diseases, fungicide sprays may be justified to protect high-value plantations. By contrast, fungicide sprays have become an essential

part of nursery and Christmas tree plantation management. Foliage diseases are capable of destroying seedlings and young trees in a short time; hence, knowledge of the various pathogens, periodic checking, and timely fungicide applications are necessary to profitable production.

Some examples of the three categories of disease are given here.

Root and Soilborne Diseases

Verticillium wilt. The fungus which causes this disease (*Verticillium albo-atrum*) is a soil inhabitant, i.e., it can live in the soil for long periods in the absence of a suitable host. It also has a wide host range including both woody and herbaceous plants. Fumigation may be used to control *Verticillium* where high-value crops such as nursery stock are produced. The planting of nonsusceptible plant species is the only other suitable control.

Shoestring root rot. This is a fungus disease caused by *Armillaria mellea*. The fungus produces stringlike black strands which may grow many feet through the soil from host to host. *Armillaria* has a broad host range among the woody plants and both conifers and broad-leafed trees are attacked. *Armillaria* is not aggressive fungus under most conditions, hence the maintenance of tree vigor is very important in protecting valuable trees. Where high-value trees are concerned, fertilization to maintain tree vigor is recommended. Once the fungus is present and causing damage, soil fumigation is the only effective method of control. Very few economically valuable trees are resistant to attack, so crop rotation with trees is not a viable solution.

Damping-off. This disease is caused by several different fungi. Those most commonly encountered are *Phytophthora, Pythium, and Fusarium.* Only very young seedlings are attacked, so the disease is primarily associated with nursery production of forest trees. Young seedlings may be infected before they emerge from the soil or after emergence at or near the ground line. Nearly all tree species, both conifers and hardwoods, are susceptible to these pathogens. The disease is generally most severe in soils that are excessively wet.

The best control is the use of proper cultural methods such as bedding, selection of well-drained soils for nursery production, and avoidance of excessive watering. In some instances effective control has been achieved by treating seeds with fungicides. Likewise, soil drenching with some fungicides has proved effective in several cases. The best control has been obtained with soil fumigation.

However, this not only destroys the harmful soil organisms, but the beneficial ones as well.

Fomes annosus root rot. This is a disease of conifers caused by the fungus *Fomes annosus*. This fungus enters a stand of trees by airborne spores which land on freshly cut stumps. Once in the stand the disease spreads by roots and root grafts between adjacent trees. This results in circular patches of dead or dying trees around stumps. The disease is most destructive in plantations where there is close spacing of trees of a single species.

Fomes annosus has been controlled by treating the freshly cut stump surface with a compound such as borate to keep the airborne spores from entering a stand. Once in a stand, trenching around trees or soil fumigation to kill root grafts between adjacent trees has been found to be effective in some high value stands. Timing of thinning to avoid freshly cut stumps at the season the fungus is producing spores has also been found to be effective to avoid introducing the fungus into a stand.

Other diseases. Several other well-known diseases use the soil and roots as a means of spreading. Examples of these are Dutch elm disease caused by *Ceratocystis ulmi* and oak wilt caused by *Ceratocystis fagacearum*. Spread of these diseases to adjacent trees is by root grafts, therefore trenching and soil fumigation to break these grafts is often used as a control.

Stem and Branch Diseases

White pine blister rust. This stem disease, caused by the fungus *Cronartium ribicola*, affects only white pine and species of Ribes (currants and gooseberries). In Michigan the disease presents a problem primarily in the Upper Peninsula and the northwest quarter of the Lower Peninsula. In these areas elimination of Ribes along with selective cutting and pruning of white pines has provided adequate control of blister rust in white pine stands. As is readily apparent, the above control measures are only practical where plantation culture is practiced.

Several other rusts are found on the stems and branches of pines. These have a variety of plants as alternate hosts. Control of these rust diseases is seldom warranted except on high value trees. Generally cultural techniques, such as pruning and selective cutting have achieved the best results in controlling these rusts.

Hypoxylon canker of aspen. Caused by the fungus *Hypoxulon mammatum*, this disease infects over 10 percent of the quaking aspen in Michigan. It often kills trees by girdling the stem. Pole-size trees can be killed in five years, while younger trees are often killed more quickly. Decay fungi may enter the cankers and weaken the tree making it subject to windfall and breakage.

No chemical controls are used for this disease under forested conditions. The best control for Hypoxylon canker is to maintain a dense stand and a closed canopy. If more than 25 percent of a stand is infected, the stand should be harvested and converted to a new species. Lightly infected stands (less than 10 percent) can be managed on a 40 year or longer rotation without suffering substantial losses.

Nectria canker. This fungus disease, caused by *Nectria galligena*, is serious on quality hardwood stands, particularly maple. It is the most prevalent and serious canker disease of hardwoods in te eastern United States. The disease normally does not kill trees, but weakens the stem and makes them subject to breakage and entry of decay fungi. There is considerable loss of merchantable volume when a tree is infected in the butt log.

The usual control method is to remove trees with trunk infections from a stand during improvement work. It is usually impossible to remove all infected trees from the stand; those that are removed should be utilized, because if left in the woods the fungus growing in them will produce fruiting bodies which will form spores to infect the nearby healthy trees. Care should be taken when logging because the fungus enter trees through small wounds. Therefore, logging of diseased trees may actually increase the prevalence of cankers if healthy trees are wounded during the logging operations.

Other stem diseases. Several diseases mentioned under root and soilborne diseases are a type of stem disease. These are Dutch elm disease and oak wilt. These diseases are found primarily in the stem, limbs, and branches of trees.

They cause a plugging of the conducting tissues of the tree resulting in a wilt and eventual death of the tree.

Control of these vascular wilts has been by use of insecticides to control their insect vectors, by controlling root grafts, and by prompt removal of diseased trees. Recently, fungicides injected into trees have been able to control Dutch elm disease. This particular disease is a good example of multiple control procedures: insect control, root graft prevention, sanitation, and fungicide control.

Foliage Diseases

Needlecast diseases. These diseases are of primary concern to Christmas tree growers and conifer seedling nurseries. All three major conifer groups used as Christmas trees are affected. Pine trees, especially red and Scots species, are affected by *Lophodermium pinastri*. Spruces, especially blue spruce, are susceptible to *Rhizosphaera kalkhoffii*. Firs are affected by the fungi *Rhabdocline pseudotsugae and Adelopus gaumanni*. These needlecase diseases can be controlled with the timely application of fungicides. Proper equipment adjustment and thorough coverage of trees are essential to good control.

Needle rusts. These rusts are found on several pines in Michigan. Alternate hosts of the needle rusts are weed species, such as aster and goldenrod. Older needles are generally attacked and the disease can be quite serious on red pine in plantations.

Control of the needle rusts is generally by cultural methods such as planting in areas away from the alternate host weeds. Weed control in young pine often lessens the severity of rust attack. *Anthracnose* — Several species of fungi in the genus *Gnomonia* cause anthracnose leaf and twig blight on sycamore, oak, ash, maple, and walnut. The disease is seldom serious under forested conditions. Walnut anthracnose can be a serious problem in nurseries and high value stands. Sycamore growing under stress conditions may have serious anthracnose problems, but if growing in a moist well-drained site, the disease is seldom serious.

Generally little is done to control anthracnose. However, walnut anthracnose in nurseries can be controlled by periodic spraying with fungicides.

Fertilization of certain high value trees will help reduce the severity of anthracnose.

SELF-HELP QUESTIONS ON FOREST DISEASES

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. Can forest diseases usually be treated successfully with fungicides?

2. List at least three diseases that are root and soilborne.

3. List at least three stem and branch diseases.

4. List at least three foliage diseases.

VERTEBRATE POPULATIONS AND PROBLEMS

Vertebrates are a normal part of a healthy forest, but at times they increase in numbers or behave in ways so that they cause damage to the commercially valuable trees. When this occurs, vertebrates become pests, and the damage they cause requires control. Most often damage by vertebrates is not intense enough to be of concern, but occasionally severe damage occurs. For example, abundant rodents or deer can totally prevent forest regeneration or destroy entire stands of seedlings and saplings.

The following is a classification of kinds of damage, cause and current remedial techniques.

Damage	Cause	Control Technique
Consumption of seed	rodents	repellants, toxic baits
	birds	repellants
Consumption of seedlings	rodents	repellants, toxic baits, physical barriers
	deer, rabbits	repellants, physical barriers, shooting, traps, silvicultural practices
Consumption of bark, branches, deformation of tree	rodents, deer, rabbits, bear	repellants, physical barriers, shooting, traps, silvicultural practices
Consumption of buds	squirrels, birds	physical barriers
Flooding of trees	beaver	dynamiting of dam, trapping, shooting

Examples of Damage Control Techniques

Repellants. Repellants are devices or chemicals that affect one or more of the senses of an animal in an irritating manner, causing it to change its behavior. Chemical taste repellants are usually the most effective, and are applied to seeds and seedlings to prevent consumption.

Physical barriers. A physical barrier is a device used to exclude animals in order to prevent damage. Sheet metal around the bole (trunk) of seed orchard trees to exclude squirrels or around the base of Christmas trees to exclude mice are examples of physical barriers.

Silvicultural practices. Damage can be prevented by forest management techniques. Increased size of clear-cuts can produce more seedlings than the deer herd can consume, or seed tree harvest can produce increased seed supplies that exceed consumption by birds and rodents.

Toxic baits. Mixed grains treated with poison can be used to reduce rodent populations that would consume seeds or seedlings.

Trapping and shooting. At times, damage may be caused by only a few individuals or be confined to a relatively small area. In these cases, shooting or trapping may be the most efficient damage control technique. Hunting during the legal season may also reduce damage, especially if the damage is caused by overabundance.

Questions to Answer

Before applying pest damage control techniques, you must answer the following four questions:

1. Will the technique work? For example, effective taste repellants may be applied to trees when planted in the spring. Subsequent growth over the summer is then browsed by deer in the winter. In this case the repellant did not fail; the applicator failed to match application to damage.

2. Is the technique efficient? Will the cost of the technique be less than the cost of the damage? Benefits should be greater than costs.

3. Will nontarget species be affected, and if so, how seriously?
Application of any pesticide that seriously reduces numbers of nontarget species should not be considered except when the alternative loss is great. No pesticide should ever be applied if its use or repeated use causes long-term reductions of nontarget species.

4. Will the reduction of pest animal numbers create additional or more serious problems.
A change in the numbers of one animal could produce changes in numbers or behavior of another animal so that one problem is traded for another.

SELF-HELP QUESTIONS ON VERTEBRATE POPULATIONS AND PROBLEMS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What types of damage might be caused by rodents?

2. What are repellants?

3. What are the four questions that must be answered before applying pest damage control techniques?

FOREST VEGETATION CONTROL

Weeds are plants that are growing where they are not wanted. In the case of most forestry operations they can be thought of as plants that interfere with achieving the forestland management objectives, either by occupying growing space which could be occupied by more desirable species or by competing with more desirable species for soil moisture, soil nutrients, and/or sunlight.

Depending on the values or resources for which the forest is being managed, the impact of weeds on trees or forests may be evaluated by the population density of the weeds (number of weeds per unit area), the visual impact of the weeds, or the effect the weed competition has on the growth of the crop species. It should be stressed that where tree growth is the major management goal, tree growth should be the major indicator of the need for and the success of weed control efforts. In such a situation there is not need to strive for 100 percent weed control if some lesser amount will achieve the desired growth. It is also worth noting that weeds are probably responsible for more lost forest productivity than all other pests combined.

Weeds may be recognized and classified many ways including by individual species (e.g., quackgrass), by groups of species (e.g., grasses), or by growth form (e.g., trees, brush, vines, and herbaceous plants). It is most convenient to examine weed control techniques in forest situations using the growth form classification. However, it is important to remember in almost all situations the type of plant to be controlled will need to be known much more accurately, in many instances to species, in order to select the proper herbicide and the correct rate and timing of application.

Weed Trees

Significant forest production losses frequently result from weed trees competing with more desirable trees for soil water, soil nutrients, and sunlight, and/or occupying growing space that could be occupied by more desirable

species. Depending on the management objectives, included as weed trees may be hardwoods and conifers of noncommercial species, defective or deformed individuals of commercial species, species growing on a site where they will do poorly (off-site species), and species that are not compatible with the management objectives of that forest stand. Examples: Noncommercial—striped maple and hornbeam; defective—diseased, insect infested, heart rot, and mechanical damage; deformed—crooked, low fork, and excessively branched; off-site—white pine on a very droughty sandy ridge; species incompatible with stand management objectives—poison sumac along trails in forests managed for intensive recreational use.

In excessively dense stands less vigorous trees of commercial species are also considered weed trees which should be removed in order to increase the rate of growth of the remaining trees. The number of trees to be removed in a particular stand will depend on the species, density, and size of the trees and the stand management objective.

Some weed trees may be suitable for a commercial harvest for sawlogs, pulpwood, or firewood. Those unsuited for commercial harvest may be removed or killed mechanically or chemically. Chemical methods include: (a) broadcast application of herbicides to the foliage and bark, (b) application of herbicides to cuts and wounds of individual trees, (c) basal bark applications of oil solutions of herbicides, and (d) soil application of granular herbicides.

Broadcast applications of herbicides may be applied to weed trees as aerial or mist blown sprays for the removal of undesired vegetation from an area prior to planting (site preparation) or for the selective removal of hardwoods in coniferous stands (release). For site preparation, total volumes of 3 to 30 gallons of water or oil containing the herbicide are applied per acre by aircraft or mist blower from early to mid-growing season. Effectiveness may sometimes be enhanced by subsequent controlled fire. Selectivity (the relative toxicity of a herbicide to different plant species) is not a major consideration in this operation.

For release, a very limited number of commercial products are registered. These are applied as when using them for site preparation, except that season of application minimizes conifer damage while controlling hardwoods. Herbicide

selectivity is very important in release and is strongly influenced by coniferous growth activity. Label instructions specify the proper season to apply the herbicide for maximum selectivity. Poor hardwood control and serious damage to conifers can result from inappropriate timing.

Aerial applications are ineffective on some hardwood species and inappropriate in many situations where only scattered weed trees are to be killed. In such situations herbicides must be applied to the individual tree. Individual stems may be treated by applying herbicides to cuts or wounds in the trunk, by basal trunk applications, or by spreading granular herbicide on the soil.

Individual stem treatment usually involves application of water-soluble salts of herbicides in concentrated form to cuts or wounds. This may be done several ways including the following:

1. Girdling, where 4 inch wide chips are removed to a depth into the sapwood so as to completely encircle the tree bole (trunk). A herbicide solution may then be applied to the girdle to hasten topkill.
2. Frilling (i.e., encircling the bole with a series of single line axe cuts which overlap and penetrate through the cambium) and then applying the herbicide as with the girdle.
3. Felling the tree and wetting the margins of the cut stump surfaces with concentrated water-soluble salts of a herbicide.
4. Trunk injection with special tools such as the tree injector or modified hatchets that inject water-soluble herbicide concentrate into the tree bole.
5. Axe cut cups spaced around the bole of the tree near the ground line into which are placed water-soluble herbicides in liquid or crystal form.

Basal bark applications of a herbicide are also an effective way of controlling small trees of many hardwood species. The process consists of spraying the bark of the lower one foot of the bole and the exposed roots to the point of run-off. Oil-soluble ester formulations of phenoxy or related herbicides are used at considerable dilution in an organic carrier such as diesel oil. The thick bark on some older trees can cause resistance and dosage requirements are high on such trees.

SELF-HELP QUESTIONS ON FOREST VEGETATION CONTROL

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. Do weeds cause a significant loss of forest productivity?

2. When may commercial species be considered weeds?

3. List at least four methods of individual stem treatment.

ADDENDUM TO "SAFE EFFECTIVE USE OF PESTICIDES. FOREST PEST CONTROL"

Extension Bulletin E-1032-2

Brush

Brush includes woody shrubs and small trees. Dense brush can limit availability of water and nutrients to desired species and also excludes light from seedlings on regeneration areas. It impedes planting and can create habitats conducive to wildlife species that damage tree seedlings.

Broadcast applications by aerial spraying are effective on susceptible species and are applied for general or selective control of brush, as well as trees. If the brush is not over 20 feet in height, mist blowers may be used for ground application; aircraft are usually used on taller vegetation. Density of the brush affects coverage. Volumes of spray, solution concentrations and swath patterns must be accurately calculated and applied to insure effectiveness of treatment. Volumes used depend on equipment and depth of vegetation.

Chemical control by individual stem application is expensive because of the numbers of stems per acre. Basal bark applications are effective but access for spraying equipment to bases is costly in labor, chemical and fuel oil.

Vines

Wild grape, Virginia creeper, poison ivy, and other vines are serious pests especially on better soils in some parts of the state. Effects include strangling of trees, dragging down branches and crowns, and competing for light and nutrients. Poison ivy is a personal health hazard for forest workers and recreationists.

Chemical control with systemic herbicides is needed to kill root systems of vines because of vigorous sprouting habits. The opportune time to apply herbicides which will control vines along with a mixture of weed trees and brush is between logging and planting. Vines, as a group, are the most difficult of these weeds to control effectively.

Mist blowers and other broadcast application methods may be used to control extensive understory vines. Individual large vines may be controlled by girdling, frilling, or injecting techniques or by cutting the vine and applying herbicide to the edges of the exposed cut surface. Soil active herbicides should not be used where damage to desirable trees could result.

Herbaceous Weeds

Herbaceous weeds in young forest plantations can cause considerable growth loss and mortality due to competition for soil water, soil nutrients, and sunlight, and also create favorable cover for tree damaging animals such as mice and moles. In more intensively managed high value plantations, such as seed orchards and Christmas trees, herbaceous weeds can reduce seed production, create a fire hazard, interfere with cultural operations such as shearing, may be aesthetically unattractive, and interfere with the growth of the lower branches.

The two economically feasible methods of controlling herbaceous weeds in forest plantations are by mechanical means or with certain agricultural herbicides if regionally or generally labelled for this use.

Where chemical control of herbaceous weeds is necessary, a residual herbicide is usually needed to extend control through the growing season. Resic herbicides are most effective when applied in late fall or in the spring before seedling growth begins. Occasionally, mixtures containing both contact and residual herbicides may be required as in the case of a late spring application when the weeds are already actively growing. In such instances either pre-plant application or the use of tree shielding is necessary to prevent damage to the trees. It is also important to note that some residual herbicides can damage tree foliage during certain seasons of the year.

Complete control of all ground cover for one or more years is generally not necessary or desirable as it may result in soil erosion and an aesthetically less attractive site. Generally, spot or band applications of the herbicide are more desirable.

The importance of proper sprayer calibration when controlling herbaceous weeds cannot be over-stressed. Most of the herbicides used to control herbaceou weed competition will kill tree seedlings if applied in excessive amounts.

PESTICIDE LABELING FOR FORESTRY

Forest lands generally produce an "agricultural commodity" which is sold, used or consumed by man or animals, so such lands are considered to be croplands. The implication of this definition is that pesticides labeled for "noncropland uses" are not generally applicable to forest situations. Consequently, legal use pesticides requires registration for forest pests or forest conditions.

Pesticides used in forests, seed orchards or nurseries must be registered specifically for these uses or combinations of crop and pest species. The pasture, range, ornamental and noncrop pesticides are not necessarily cleared for forests unless uses identifiable with forestry are stated, or forests are included in range management uses.

Pesticides registered for use in forestry often are tank mixed. In mixtures of two or more products, the rate of each component may not exceed the rate prescribed on its label. When such mixtures are used, the user assumes all liability for damage to desirable species when in excess of that expected from labeled uses.

Forest insecticides and fungicides may be used to combat widespread epidemics and to spot treat individual plots in nurseries, seed orchards and Christmas tree plantations. Because their use is not general in forests, very few materials are registered specifically for broadcast forest use on the label. Because these chemicals are needed for some forest insects and diseases, applicators need to know these features of forest operations:

Large-scale applications of insecticides by aircraft usually require special approval. This may be granted for local outbreaks by the issuance of state labels. Projects which include many ownerships are usually coordinated by state forestry departments and the U. S. Forest Service Division of State and Private Forestry within regions.

Small-scale applications to nurseries, Christmas trees and seed orchards are covered by registrations for ornamentals where target insects and diseases appear on the label.

SELF-HELP QUESTIONS ON PESTICIDE LABELING FOR FORESTRY

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. Are pesticides labeled for "noncropland uses" generally applicable to forest situations?

2. Do large-scale applications of insecticides by aircraft usually require special approval?

SPECIAL FORESTRY APPLICATION EQUIPMENT

Aerial Application

Aircraft are commonly used for applying pesticides to forests. A few considerations when using aircraft need to be emphasized.

Drift control is more difficult to achieve in forests than elsewhere because of the greater application heights. Methods that are in general use include:

- The use of a nozzle system or spray additives that modify droplet size.
- Using nozzles that eliminate fine drops.
- Decreasing boom pressure.
- Increasing the size of orifice of the nozzle.

Increasing droplet size decreases the time that drops hang in the air, thereby reducing their ability to move off target. However, the nozzles in general use do not eliminate small droplets altogether and may require more volume for the same coverage and effect. Thus, the use of large droplets either increases volume requirements or decreases effectiveness of many pesticides. It is variably effective in reducing drift, deperding on whether small droplets are substantially eliminated.

Special nozzles are available which produce uniform droplets, with very large and very small drops not present. This intends to provide uniform application with maximum drift control. These systems also have a tendency to produce a somewhat larger average droplet size than conventional nozzles, and may also require more volume per acre to achieve a given effect. The use of spreaders will compensate to some degree for the loss of effectiveness of pesticides due to the large droplet size.

For most aerial application systems, a measure of drift control can be obtained by proper orientation of spray nozzles. Nozzles directed toward the rear have less wind shear, and do not atomize the spray as much as those directed downward. Some helicopter operators have found the 45° orientation directs the nozzles into the rotor wash with minimum breakup, whereas airplane equipment

requires greater orientation to the rear to compensate for the greater air speed.

Aerial applications of pesticides are more effective and less likely to have troublesome drift when applied at low level. Snags and tall trees should not stand above the general vegetation level; if the aircraft must fly above them, a high percentage of the spray may evaporate while falling. Fine droplets drying this way turn to dust or vapor that may cause unacceptable loss of chemical. Under such circumstances the incidence of drift is substantially increased.

When sensitive crops or boundaries are not in the vicinity, the use of fine drops provides better coverage, and often greater effectiveness of the pesticide. Thus, coarse sprays are not always beneficial.

Guidance of aircraft over forested areas is difficult. Areas to be treated must be marked so as to be clearly visible from the air. Balloons, smoke, bright color panels or flagging devices are commonly used.

Mist Blowers

Mist blowers are mechanical units into which is directed a stream of the pesticide solution. These devices have the ability to break up spray droplets into finely atomized particles which provide excellent coverage of the target, but which, owing to the small size of the droplet, are highly susceptible to drift under favorable weather conditions. When using a mist blower in forests,

Do:

- Apply only under favorable weather condition (winds less than 5 mph).
- Be extra careful of drift when applying herbicides with a mist blower.
- Follow nozzle pressure less than 20 p.s.i.

Don't:

- Use high spray pressure.
- Use a nozzle that produces fine droplets.
- Use under stands of sensitive desirable trees when applying herbicides.
- Use near recreation areas.

Tree Injectors

Tree injectors are instruments that make a wound through tree bark in which a small amount of an herbicidal solution is placed. They take the form of a pipe with a chisellike bit on the lower end, or that of a hatchet with built-in calibrated pump.

Injectors are used to control woody species that have passed the "brush" stage, and can be treated on an individual stem basis. Hatchet types are used at a convenient level and the chisel types are directed at the base of the tree. Injections are usually spaced one to four inches apart, depending on species and chemical.

Herbicides used in injectors deserve special comment. They should be water soluble salts—amines, potassium salts, sodium salts. Esters do not translocate well when injected. Operators are likely to be exposed to concentrates in the process of injection on a day-to-day basis. Although these materials, even the arsenicals, are not considered especially harmful, crew training to minimize exposure is necessary.

Directed Spray

Herbicides that provide effective weed control may include some materials that will damage the desired trees. Hand sprayers equipped with shields or with directional nozzles can be used to prevent damage to seedlings. Such equipment can also be mounted on tree planting machines so that herbicides are applied at the same time seedlings are being planted.

Applicators should observe all normal precautions in the handling of general use pesticides when operating in forests. The remoteness from habitation does not imply that the operator should be less careful than in settled areas. Attention to target definition and watercourses is always critical. If additional precautions are required for restricted-use pesticides, they will appear on the label. READ THE LABEL CAREFULLY!

SELF-HELP QUESTIONS ON SPECIAL FORESTRY APPLICATION EQUIPMENT

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What are some of the methods generally used to control drift?

2. Should you use high spray pressure when using a mist blower in forests?

3. What formulations of herbicides are suitable for use in injectors?

4. What can be done to prevent herbicide damage to seedlings?

SPECIAL PRECAUTIONS FOR PESTICIDE USE IN FORESTS

It is the applicators' responsibility to take certain steps to minimize adverse effects of pesticides. They should be familiar with pest problems in the local forests, and with effective and legal treatments for their control. Although the manager prescribes what is to be applied, the applicator shares the liabilities if damages result. Be informed.

Part of being informed is having a clear understanding of the boundaries of the area(s) to be treated. Forests are often not clearly marked between ownerships. Applications made without adequate marking give poor results. These discredit the applicator and may cause unnecessary environmental damage. The applicator must reach an understanding with the manager as to what sorts of guidance he will need to do an acceptable job.

It is important to avoid application of any pesticide to open water unless the product is registered for aquatic or streamside use. Because nearly all pesticides remain where applied unless moved by soil erosion, the avoidance of open waters will prevent most problems associated with water contamination.

Public relations are extremely important when applying pesticides to a forest. It is the joint responsibility of landowner and applicator to see that neighboring landowners are not subjected to acts of trespass. As a matter of courtesy it is a good idea to inform adjacent landowners and neighbors in advance of any large-scale application.

Pesticides have been categorized according to general use or restricted use. Applicators need to be certified to handle restricted-use pesticides and to be well informed regarding general-use pesticides.

SELF-HELP QUESTIONS ON SPECIAL PRECAUTIONS FOR PESTICIDE USE IN FORESTS

Now that you have studied this sect, answer the following questions. Write theanswers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. Does the applicator share the liabilities if damages result from pesticide application?

2. Do most pesticides remain where applied unless moved by soil erosion?

ACTION OF PESTICIDES IN THE FOREST ENVIRONMENT

Every part of a forest changes somewhat when another part is removed. Since pesticides act by removing various living things, it is appropriate to consider the general way in which the entire forest responds when a pesticide is used on a particular target species. Although the target may be the only organism injured directly by the pesticide, it is important to understand which other organisms depended on the one(s) removed.

The pesticides used in forests, i.e., phytocides, insecticides, rodenticides, repellents, and fungicides, are, in general, specific in injuring plants, insects, vertebrates, other animals, and fungi. The general discussion of their effects can therefore be grouped by class of pesticide.

Phytocides

This class of chemical includes a small number of chemicals actually registered for use in forestry. Some are used exclusively for removing large woody vegetation, some are used for general control of woody and other broadleaf plants, and some are used for grasses and broadleaf herbs exclusively.

Trees affect every other living thing in the forest in a major way. Removal of trees by any means causes a great increase in soil moisture, nutrients and light available for the vegetation that survives. Thus, logging, herbicide application and girdling have many features in common. The most important impact of tree killing is the release of site resources, followed by the increase in development of ground vegetation and forest regeneration. This is a significant ecological principle in the regeneration of light-demanding tree species and in management of wildlife management of wildlife habitat.

Brush-killing herbicides are used for the specific purpose of improving the competitive positions of desirable tree species. It is important to recognize that all species not injured seriously by the herbicide are similarly benefited, including tree seedlings that are competitively able to dominate the other vegetation.

When chemicals are used for removing only a part of the tree cover, the remaining trees tend to use many of the resources released. It may take up to several years for the trees to occupy the vacated space, during which time the ground vegetation prospers, then declines.

Some brush-killing herbicides are more persistent than others. These tend to be more effective in controlling large woody vegetation than the others. Similarly, when short-persistence herbicides are used to kill trees, survivors are likely to recover quickly. At recommended rates of use, none of the registered woody plant herbicides persists long enough to cause prolonged devegetation.

The removal of trees and/or shrubs from the forest usually increases the amount and diversity of wildlife food available in the area and alters the type, distribution, and amount of cover available. As a result, changes in the type, number, and distribution of the animals occupying the area often occur. Over time the forest gradually reverts to its original structure and the type, number, and distribution of animals in the area changes correspondingly. These changes are caused by the forest, not by the herbicide; the chemical was merely the tool that initiated the changes. Variations in chemical effect have an influence on the types of changes and the rates at which they occur.

Control of ground vegetation in preparation for reforestation temporarily removes much of the plant cover. Herbicide-resistant or untreated trees show a response similar to that produced by fertilization and irrigation due to the increased availability of soil moisture, soil nutrients, and/or sunlight. Devegetation can cause the loss of topsoil or soil nutrients if soil remains bare during periods of rain. It will also cause a marked decrease in most wildlife activity during the period of devegetation. Removal of vegetation may result in a deeper penetration of frost into the soil which can affect both beneficial and harmful soil organisms.

Herbicides are generally quite immobile in forest soils. The only potential problem may occur on areas devegetated sufficiently to allow erosion. Eroding soils may carry herbicides with them. Herbicides are degraded in place by microorganisms, sunlight and chemical reactions. A compound that has an effective life of several months will usually not have traveled in solution more than a foot or two from the site of application unless erosion has occurred. They therefore do not pose a serious threat to water supplies, and have negligible effects on fish as the result of movement in soil. It has been demonstrated that herbicides will not occur in water in biologically active amounts if they are not placed directly into forest streams or washed in an eroding soil.

Insecticides

Insecticides usually have little direct effect on forest vegetation. They do not have such major effects on the entire forest as woody plant herbicides do. Because these chemicals are highly toxic to certain animals, it is important to understand which array of animals will be affected, and how this will affect the rest of the forest.

Some insecticides are highly specific in their effects on insects and their relatives. If the insecticide is short-lived, it will have a very transient effect on the forest, having temporarily decreased the abundance of certain insects. Some birds and small mammals that prey on the victim insects will have reduced food supplies, but if the insecticide is not persistent or does not accumulate in fat, these predators will probably not be harmed substantially by secondary poisoning. If the chemical is persistent, there is greater likelihood of accumulating harmful amounts over a period of time.

Certain compounds are chronically toxic, others are acutely toxic. Chronically toxic materials do not readily kill with one large dose, but are potent when administered in small amounts over a long period. If a large enough dosage is present, the acutely toxic materials will cause immediate death. A sub-acute dose will not likely produce direct effects later. Most insecticides used in forests are acute toxicants. Many require large dosages to produce acute effects in mammals.

Because insecticides are animal poisons, they present the possibility of secondary poisoning of "food chain accumulation." This occurs when predators consume numerous prey that contain some of the insecticide. If the prey contains some oil-soluble insecticide, this may be retained in the fat of the predator, causing its body load of insecticide to be greater than that of its food supply. This may eventually cause injury to the predator or to the larger predator that consumes it. Because of this problem, the organo-chlorine insecticides are not likely to be used extensively in forestry again, even though this danger is minimized by infrequent application.

Many insecticides, being poorly retained in fat, do not build up or have other cumulative effects. They tend to degrade rapidly, with the result that after an immediate collapse of sensitive populations, the remaining insects breed and are complemented by invading insects until the carrying capacity of their habitat is reached. Insectivores consuming insects with large insecticide deposits may be injured, and their effectiveness as beneficial predators reduced. This can cause resurgence of the pest. However, there is a wide variation in the selectivity of insecticides and some, such as biological control agents, are noted for their lack of injury to nontarget organisms. The applicator should familiarize himself with possible alternative materials for protecting forest crops, and use a prescribed registered product with the greatest specificity for the damaging insect.

Insecticides can cause considerable injury to fish populations. Very low concentrations of certain products in water can temporarily decimate a fishery. Like herbicides, insecticides are not highly mobile in soil unless the soil erodes. Insecticides should be kept away from open water by leaving adequate buffer strips along streams and impoundments.

Rodenticides and Repellants

Very small amounts of rodenticides are used in forests. Most of the rodenticides used are highly toxic to mammals but may not have an adverse effect on the plant's environment owing to the minutely small dosages used.

The most important objection to the use of rodenticides is the hazard they present to nontarget animals attracted to baits or consumed by predators. The use of toxic chemicals probably causes the least disruption in the ecosystem

of any direct method of forest vertebrate control because of selectivity and the lack of physical impact.

Because of the reproductive potential and movements of most pest animals, baited areas are soon restocked with target animals, rendering this method ineffective for long-term problem solving.

Repellants are used to obtain short-term protection until the protected plant is beyond the susceptible stage. Environmental hazards from repellants and their use are minimal.

Fungicides

Fungicides are used in forestry principally for protecting nursery beds from several important diseases, and in Christmas tree plantations for controlling certain foliage diseases.

The most common fungicide applications in nurseries include soil fumigation prior to seeding. The fumigants are general biocides—killing seeds, fungi, soil insects, nematodes and earthworms. Because of the very limited acreage of forest nurseries, these treatments do not have an effect on the general environment. In the nursery, however, their effects on all biota including beneficial fungi, bacteria, insects, and earthworms are severe. Of the other fungicides used for stem, branch and foliage disease control, none are known to affect nontarget organisms, except possibly nontarget fungi and no cases of secondary poisoning are known with the fungicides currently in use. Even so, fungicides should be used with due respect and contamination of streams and impoundments should be avoided.

Forest seedlings depend on beneficial symbiotic fungi, called mycorrhizae for their survival and growth. These fungi occur on hardwoods and conifers and function by greatly increasing the absorptive capacity of the root system. Seedlings can and do grow without them, but with less vigor, and with less chance of survival in the field after transplanting. The loss of beneficial fungi is usually temporary, because the wind-disseminated spores usually restore the soil microorganisms rapidly.

The loss of fungi in soil may reduce the ability of the soil to retain nutrients.

Nonchemical Methods

Many weed problems are handled by machinery. Tractor scarification, brush chopping and fires have major physical effects on soils, watersheds and wildlife habitat. Soil compaction and siltation are not uncommon, although usually of minor long-term significance. These effects do not occur when using herbicides for the same objectives.

An important nonchemical option is nontreatment. Because of the continued effect of the pest, this option may have a great impact on the forest environment over a long period.

SELF-HELP QUESTIONS ON ACTION OF PESTICIDES IN THE FOREST ENVIRONMENT

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List at least five consequences of the chemical or physical removal of trees.

2. What is "food chain accumulation"?

3. Is baiting an effective long-term solution for rodent control in forests?

4. What are mycorrhizae?

5. Are soil compaction and siltation usually significant on a long-term basis?

HAZARDS OF PESTICIDE USE AND NONUSE

Whenever a pesticide is to be used, the decision to use it should consider the species affected adversely by its use as well as those affected by nonuse. A forest is a constantly changing environment as trees grow and are removed. Even without pesticides, major changes in the forest frequently occur because of such factors as fire, insects, wind, ice storms, and diseases. Environmental hazards from pesticides are those undesired changes in the forest ecosystem produced by the pesticide.

Fish are particularly sensitive to certain insecticides applied directly to water. Mortality is particularly severe in slow-moving streams. Fish populations may also suffer decreased growth due to the decreased production of insects, but the ability of a stream to support fish is not impaired after the insecticide is gone. Insecticides may be flushed out or inactivated by adsorption to organic surfaces, where they are usually degraded to relatively harmless materials.

Insecticides of different groups have different effects. Those that are quickly degradable influence only the organism killed immediately. Because of the rapid disappearance of the chemical, survivors tend to be unaffected. Dosages are seldom high enough to cause injury to most vertebrates. Birds are the most likely to be affected.

In addition to their effects on vegetation, herbicides that remove herbaceous cover in forest plantations have an indirect effect on mice and other small mammals that depend on ground cover for food and protection. Changes in these mammal populations may or may not affect the survival of planted tree species, and may be either desirable or undesirable.

Herbicides applied by aircraft unavoidably appear in small quantities in

forest waters. As the same materials are often used in aquatic weed control, they are not likely to cause unreasonable adverse effects if every effort is made to avoid applying them to open water. Other herbicides can cause severe damage in watercourses and are strictly prohibited (on the label) from use near open water.

Pesticides used in forests seldom come in contact with humans at exposure rates high enough to cause injury. Low dosages, spread high in the trees or distributed in a heavily vegetated area, are not picked up in significant amounts in normal human activity. Except for the most toxic insecticides, direct exposure to aerial application is of minor importance. An exception is when flagmen are exposed to repeated applications. Humans consuming game animals that have been feeding in treated areas are likely to consume residues that exceed federal tolerances for domestic meat production. Herbicides are generally below detection limits in the flesh of wild herbivores.

A major area of concern with forest pesticides relates to drift damage, especially with herbicides. Sensitive crops are sometimes injured by fine droplets moving off the target area or by movement of fumes. Illegal pesticide residues in food crops can be another consequence of drift.

Damage to nearby agricultural crops and ornamental plants is greatest under the following conditions:

- High temperature
- Strong wind velocity
- Short distance to nontarget crop
- Highly sensitive crop, such as grapes, beans, tomatoes
- Application at time of maximum crop sensitivity
- Very fine droplet size
- Aerial application at higher than recommended altitudes.

The most important potential adverse effects of forest pesticide use are:

- Potential damage to desirable trees (herbicides)
- Temporary change in wildlife habitat (herbicides)
- Drift damage to adjacent crops (herbicides, insecticides)
- Danger to applicator (all pesticides)
- Danger to birds and mammals (certain insecticides, rodenticides)
- Injury to fish (insecticides)
- Injury to ground personnel, flagmen, forest workers (all pesticides)
- Soil damage from prolonged devegetation by repeated use of residual herbicides

The consequences of pesticide use always needs to be balanced against those of nonuse. Unique to forestry, the effects of nonuse may last for many decades.

An alternative to the use of herbicides in forest situations is the use of mechanical methods for controlling unwanted vegetation. However, these methods are not entirely satisfactory since root and stem injury to the desirable plants may occur. Increased soil erosion may be a consequence on some sites. With either herbicidal or mechanical control methods, the principal effect of not using any method for controlling undesirable vegetation may include (1) increased tree mortality, (2) reduced growth rate of existing trees, (3) the prevention of desirable species from growing, and (4) damage to wildlife habitat.

The effect of nonuse of an insecticide to an insect epidemic can range from total destruction of a forest to a long-term change in species composition.

Nonuse of fungicides may mean severe economic loss in a nursery added to reforestation failure in areas to which seedlings were to be shipped.

The principal effect of not using rodenticides when needed in reforestation areas may be to prolong the time needed for reforestation. Seedlings getting a late start are also more likely to need a release application of herbicide.

SELF-HELP QUESTIONS ON THE HAZARDS OF PESTICIDE USE AND NONUSE

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What are the effects of pesticides on fish in severe slow moving streams?

2. Do low dosages of pesticides spread high in a forest area come in contact with humans?

3. Is there an exception to this type of application?

4. Name five conditions under which agricultural crops and ornamental plants suffer through drift damage.

5. In using a mechanical method for controlling unwanted vegetation, what two injuries could occur?

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